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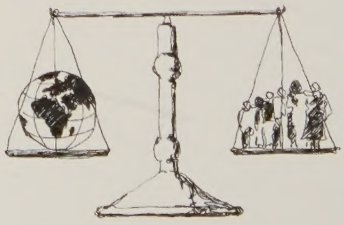

"Sustaining Earth and its People"

Scales image: Design, George Eisele, Lincoln, NE; artwork, Pat Scullion, ASA/CSSA/SSSA, Madison, WI, USA

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Editorial

Dr Garth Youngberg and Suzanne DeMuth have made a fundamental contribution to the literature on organic and sustainable agriculture with the recently published first view article: Organic Agriculture in the United States: A Thirty-Year Retrospective. Youngberg is qualified uniquely to author such an authoritative piece as he was the founder of the Henry A. Wallace Institute for Alternative Agriculture and the *American Journal of Alternative Agriculture*. He also co-authored the influential *Report and Recommendations on Organic Farming* published by the US Department of Agriculture in 1980. Ms DeMuth also worked at the Henry A. Wallace Institute as a research librarian.

In their paper, Youngberg and DeMuth trace the policy history of organic agriculture in the United States as well as its growing popularity with consumers and farmers. They provide new perspectives on the historical development of organic agriculture and how it has linked with concepts of sustainability: at times organic and sustainable approaches have been in sync and other times in competition for resources and attention. The growing organic market, nationally and internationally, due in part to USDA certification of the organic label, has solidified organic farming's position in the agricultural economy. Today, organic agriculture and food manufacturing is a recognizable and regulated symbol of environmental protection as well as a source of satisfying and safe food. To discern how this has come about, one should read Organic Agriculture in the United States: A Thirty-Year Retrospective.

Rick Welsh
Editor-in-Chief

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Organic agriculture in the United States: A 30-year retrospective

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Abstract

Since the early 1980s organic agriculture has undergone enormous growth and innovation in the US and throughout the world. Some observers have pointed to the US Department of Agriculture's 1980 *Report and Recommendations on Organic Farming* as having provided the catalyst for many of these developments. It is important, however, to understand how the evolving character of organic ideology during the 1960s and 1970s helped lay the foundation for moving organic agriculture onto the US governmental agenda in the early 1980s. We explore these and other contextual factors surrounding the USDA Report's release, including its methods, findings and recommendations, and both positive and negative reactions, as well as those factors that led to the Report's declining influence by the decade's end. The need for agricultural sustainability has played an important role in shaping, not only the path of organic agriculture in the US but also the overall politics of American agriculture. Legislative efforts to support organic agriculture have evolved along with this altered policy environment and are considered here within the broader context of the politics of sustainable agriculture. Next, we consider the organic industry's transition from a privately managed enterprise to the pivotal role now played by the federal government in the administration of the National Organic Program. Calls to move 'beyond organic' are also examined. Finally, we explore the impact of sustainable agriculture, agricultural research and farm structure upon the future of organic agriculture in the US. The politics within these three interrelated domains of public agricultural policy will likely bear heavily upon the future of organic farming and the organic industry as a whole.

Key words: organic farming, organic agriculture, sustainable agriculture, alternative agriculture, organic ideology, R. Rodale, US Department of Agriculture, agricultural research, agricultural policy, legislation, organic marketing, USDA Certified Organic, beyond organic

Introduction

During the past three decades in the US, indeed, throughout much of the world, we have witnessed remarkable innovation and growth in the field of organic agriculture. Interestingly, however, few (if any) advocates, practitioners or analysts foresaw the magnitude of these impending changes. In 1976, for example, the editor of a leading organic monthly, *Acres U.S.A.*, had this to say about the future prospects for what he called eco-agriculture: 'What you have here is a slowly evolving technology ... It will be at least a generation before the USDA [US Department of Agriculture] recognizes us ... We're off to a slow but sure start'[1]. Despite this forecast, most members of the organic farming community remained stubbornly convinced that they were on the right track, that time and circumstances were on their side, that chemically based, conventional agriculture was destined to falter, and that they would keep 'fighting the battle,' as Walters put it, for however long it might take.

While the improving prospects for organic agriculture may have eluded the purview of agricultural observers during the 1970s, there was growing recognition among a small cadre of political scientists, rural sociologists and agricultural economists that important societal changes and new political demands were beginning to alter the agricultural policy landscape [pp. 129–255][2]. Among those who saw these changes coming was Don Paarlberg, distinguished professor of agricultural economics at Purdue University, who served ably in USDA subcabinet positions in three Republican administrations. Paarlberg saw an expanding agenda for US agriculture and predicted that its proponents would marshal a significant challenge to the advocates and gatekeepers of the traditional farm policy agenda[3]. Declaring that '[t]he agricultural establishment has, in large measure, lost

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control of the farm policy agenda,' Paarlberg pointed to such policy issues as food stamps, school lunch programs, environmental protection, rural development, land use, civil rights and collective bargaining for farm workers as matters 'placed on the agenda over the protests of the agricultural establishment' [p. 96][4]. According to Paarlberg, the agricultural establishment included 'the farm organizations, the agricultural committees of the Congress, the Department of Agriculture, and the land-grant universities' [p. 95].

Many of these 'new agenda' issues overlapped with the ideological orientation and policy objectives of organic farmers and their supporters. Paarlberg, however, in his otherwise prescient observations regarding the evolving character of US farm policy, failed to include organic farming in his portrayal of the new agricultural agenda. At the time when agricultural policy analysts, such as Paarlberg, had begun to recognize the broad outlines of a new agricultural policy agenda, the organic farming movement was quite small and its core ideology was conspicuously apolitical. In terms of national policy, the organic community was unorganized, politically inactive, and thus virtually undetectable in the national policy arena. Moreover, with Secretary of Agriculture Earl Butz proclaiming an anti-organic message to a receptive conventional agriculture community—asserting that 50 million Americans would starve to death if the country were to switch to organic farming techniques[5]—it would have been difficult for any analyst to predict that organic agriculture would soon achieve a measure of recognition and influence within national agricultural policy circles.

In the 1970s, conventional agricultural science, ideology, and policy largely reflected and promoted the specialized, chemical-intensive, high-tech, export-oriented industrial agricultural model that had emerged, and then quickly accelerated, in the post-World War II period. That model, when combined with conventional agriculture's negative critique of organic farming, sent a clear message to the organic farming community: organic systems would have no place in the future of American agriculture. Given this political and ideological context, organic farmers largely avoided the policy process, choosing to withdraw from a system of agricultural politics and science that appeared to be uniformly opposed, even hostile, to them, both philosophically and scientifically. Other features of the movement's overall ideology—anti-materialism, anti-corporatism, a general distrust of large public and private organizations, and a preference for personal and political independence—reinforced its apolitical stance, particularly at the level of national policy.

Given this evolving admixture of politics, economics and technology, organic farming, when viewed through the lens of conventional agriculture in the 1970s, seemed trivial and out of touch, trapped in the grip of its own ideology, hampered by symbols of the past that it seemed to represent, and overwhelmed by the tides of change sweeping through American agriculture. Only in retrospect can we see how its ideology and technology would soon place organic farming solidly within the framework of an expanding and increasingly influential new agricultural policy agenda.

Organic Farming and the New Agricultural Agenda: The Convergence of Ideology and Politics

The new food and agricultural policy agenda identified by Paarlberg, and other analysts, during the mid- to late 1970s [pp. 129–255][2] evolved alongside a complicated mix of broader societal reform movements that had begun in the 1960s and continued to gain momentum during the following decade[6]. The durability of the new agricultural agenda can be explained, at least in part, by its ideological convergence with these broader, largely non-agricultural, reform movements. The new agenda also gained strength from various concerns that arose from within the ranks of the conventional agricultural establishment itself. These traditional gatekeepers of agricultural policy could no longer ignore such troubling externalities as soil erosion, ground and surface water pollution, threats to human and animal health from excessive use of agricultural chemicals, the demise of small farms and rural communities, and a growing chorus of criticism, from both internal[7] and external[8] voices, regarding public agricultural research priorities and funding mechanisms.

This combination of an expanding and politically astute coalition of supportive new agenda groups; growing concerns from within conventional agriculture itself regarding the negative impacts of modern production agriculture; a large and somewhat bewildering array of broad societal reform themes, issues and new ways of thinking; and, finally, a bold and unexpected USDA organic farming study launched in 1979[9], helped pave the way for organic farming to move onto the national agricultural policy agenda in the early 1980s. In order to show how these developments helped clarify the relevance of organic farming to the goals of the new agenda—and to the challenges of American agriculture—we turn first to the ideology and politics of the organic farming movement.

The ideology of organic agriculture

During the 1960s and 1970s, organic farmers held a decidedly dim view of conventional farming trends and technologies, objecting to the increasingly heavy reliance of these systems on petroleum-based production inputs, especially in the form of pesticides and synthetic nitrogen fertilizer. Organic farmers were also concerned about ever-larger farms, larger and more expensive farm machinery, corporate farm ownership, specialized production schemes [such as crop monocultures and large confined animal feeding operations (CAFOs) and increased use of

animal drugs], water resources, food quality and safety, personal health and safety, and the gradual decline of family farms, small rural communities, and localized food marketing and processing facilities. These concerns were not unique to organic farmers but were widely shared, in varying degrees, by most new agenda participants, some elements of the larger reform movement, and a growing number of consumers[10].

Having a clear sense of what could be done to help address these growing concerns would distinguish the organic farming movement from other elements of the new agricultural agenda. When consumers expressed concern about pesticide residues on food, organic farmers offered pesticide-free food; when the conservation community voiced concern over soil erosion and compaction, water pollution or loss of wildlife habitat, organic farmers insisted that their production systems minimized these impacts; when rural development advocates called for the revival of small rural communities, organic farmers noted the connections between small farms and viable rural towns. It would be decades before agricultural scientists and policy makers would begin to seriously explore the validity of these and other claims. However, many new agenda participants (and other reform groups) did come to accept and promote organic farming and its potential for addressing these problems and concerns.

Ideological leaders. In the debates surrounding the future direction of American agriculture during the 1960s and 1970s, proponents of organic agriculture drew upon a rich ideological heritage. It would be hard to overstate the importance of this ideology in sustaining the work of organic farmers and their supporters during this uncertain period. As Robert Lane, a noted authority on the subject of ideology, wrote some 50 years ago, most ideologies 'have a body of sacred documents (constitutions, bills of rights, manifestoes, declarations), and heroes (founding fathers, seers and sages, originators and great interpreters)' [p. 15][11]. The history of organic agriculture produced many such heroes and sacred documents[12,13]. Here, only a few of the more prominent American and European organic 'seers and sages' are highlighted, particularly those who appear to have exerted the most direct influence upon the debates of the 1960s and 1970s.

The late Robert Rodale, long-time editor and publisher of *Organic Gardening and Farming* magazine, arguably, was the leading voice for the organic farming community up until his untimely death in 1990, the tragic result of an automobile accident. Throughout his career, Rodale drew upon a well-formed set of underlying philosophical themes. His father, J.I. Rodale, founder of *Organic Gardening and Farming* magazine, exerted enormous influence over his son. Further, according to Rodale's own words, three additional 'sages' greatly influenced his thinking [pp. 14–16][14]. First, Rodale regarded Charles Darwin's book, *The Formation of Vegetable Mould, through the Action of Worms, with Observations on Their Habits*, published in 1881[15], as a classic in the field of organic agriculture. Second, F.H. King, former chief of USDA's Division of Soil Management, according to Rodale, made 'even more direct contributions to the origins of organic farming theories and practices ... '. Dr King was 'extremely impressed by the careful handling of organic materials by all Oriental farmers—a direct contrast to the wasteful and destructive methods of many American farmers.' King's book, *Farmers of Forty Centuries* (1911), dealing with intensive agriculture in China, Japan and Korea[16], was regarded by Rodale as a major contribution to the organic farming movement. Finally, Rodale cited Sir Albert Howard, 'who is considered the father of organic farming.' From his classic book, *An Agricultural Testament* (1940)[17], to his so-called Indore method of composting developed while serving as director of the Institute for Plant Industry at Indore, India, and his work as associate editor of *Organic Gardening and Farming*, Howard had earned a hallowed position in the history of organic agriculture. As he stated in 1976, Rodale believed that 'the organic farming and gardening idea thrives as a continuation of [the] ideas' of these three men[14].

While some observers viewed Rodale's ideas as overly purist and thus unrealistic, these charges subsided in the early 1980s when the Rodale Research Center unveiled a series of long-term, comparative cropping trials that attracted considerable attention from within the conventional agricultural science community[18]. These trials, designed by Richard Harwood, a well-known conventionally trained scientist, conformed to conventional scientific protocols and were aimed at addressing a number of agronomic questions pertaining to the performance of organic cropping systems and the informational needs of larger-scale organic farmers. *The New Farm* magazine also contributed substantially to the Rodale image as spokesperson for the full spectrum of organic growers, including large-scale conventional farmers wishing to transition to less chemically intensive and expensive approaches. These and other initiatives ensured that Rodale himself, and the entire Rodale enterprise, would constitute the single most influential political and intellectual force within the organic agriculture movement of the late 20th century.

With the death of Rodale in 1990, however, and the emergence of scores of supportive new agenda nonprofit groups, legislators, industry leaders, marketing associations, food writers, nutritionists, film documentarians and farm journalists; expanding numbers of organic producer and certification organizations; and a growing contingent of agricultural researchers and administrators, the Rodale organization gradually assumed a somewhat lesser, though still significant, role within the overall organic farming movement.

E.F. Schumacher's influence during this period was enormous, not only among organic farmers, but just as importantly, among other reform elements—such as the 1970s back-to-the-land movement—that would come to

practice and support organic agriculture. With publication in 1973 of *Small is Beautiful: Economics as if People Mattered*[19], Schumacher became an instant celebrity in both academic and nonacademic circles. The similarities among Schumacher's ideology and the ideologies of various new agenda groups were unmistakable. It was also apparent that he himself was, in turn, influenced by the thinking of various reform groups, as well as such religious philosophies as Zen Buddhism and Christianity, plus Gandhi and Thoreau, to highlight just some of the more prominent ideological themes appearing in *Small is Beautiful*.

Dr William Albrecht, long-time professor in the Department of Soils at the University of Missouri, stands out as one of the earliest and most influential academic spokespersons for organic farming ideas. Although he retired in 1959, he continued to write about the connections between soil quality and human and animal health nearly up until his death in 1974. His role from the 1940s through the 1960s was vitally important at a time when the organic farming movement and its technologies lacked academic support and credibility.

Albrecht's work would be chronicled and popularized by Charles Walters, Jr[20], who, as editor and publisher of *Acres U.S.A.*, would himself become an influential figure among a certain segment of larger-scale organic producers (or as Walters preferred to call them, eco-farmers), and the newly emergent organic farming production input and supply industry: companies that manufactured and sold various kinds of natural soil amendments and crop protection technologies. Walters was a staunch supporter of these companies and technologies.

This brief review of organic agriculture's more influential 'seers and sages' would not be complete without mentioning the contributions of Jim Hightower and Wendell Berry. Their major works of this period, Hightower's *Hard Tomatoes, Hard Times* (1973)[8], and Berry's *The Unsettling of America* (1977)[21], influenced the thinking of individual citizens and the leaders of major agricultural research institutions. Hightower's critique of land-grant university research priorities would set off a contentious debate over the impacts of these priorities on small farms and farm workers. Berry's more poetic yet powerful review of agricultural and farm structure trends also represented a challenge to land-grant university priorities. For thousands of new agenda participants and ordinary citizens, these writers helped 'connect the dots' between agricultural research and other areas of public policy, and the environmental and societal effects of conventional agriculture.

Finally, the philosophical underpinnings and public policy goals of both organic farmers and their ideological spokespersons converged with, and benefited from, the broad-based, powerful, even transformational, ideas and reform agendas of the 1960s and 1970s[6]. This was an era, for example, that saw: the emergence of modern environmentalism; Rachel Carson's influential critique of the negative effects of synthetic pesticides[22]; the Civil Rights and Women's Liberation movements; calls for participatory democracy ('power to the people'), and a loss of faith in large organizations, both public and private, energized, in part, by the anti-war movement; Earth Day, with its plea for a broad societal commitment to addressing a host of emerging environmental threats such as global warming and ozone depletion, and for new technologies and programs such as recycling and solar energy that could help alleviate our dependence on fossil fuels; the introduction of new terms such as ecological economics, deep ecology, ecological accounting and industrial ecology; and, finally, the first opportunity to look back at Earth from outer space and behold its seeming fragility.

These and other broad reform themes supported the very idea of change, and the need for new ways of conducting society's business. The new agricultural agenda groups, and likewise the organic farming movement, would benefit politically from this larger, unprecedented wave of reform and the new ways of thinking that it engendered.

Basic ideological concepts and core beliefs

Nature is capital. Organic farmers during the 1960s and 1970s believed that modern man had lost touch with nature, that he had become insensitive to nature's intricate, delicate and immutable laws. As Schumacher put it, man no longer sees 'himself as a part of nature but as an outside force destined to dominate and conquer it. He even talks of a battle with nature, forgetting that, if he won the battle, he would find himself on the losing side' [p. 13][19].

Organic farmers agreed with Schumacher's assessment of the problem. According to Schumacher, man's failure to see the difference between income and capital and to recognize the importance of the capital nature had provided (and which was being consumed at a rapid rate) had created a tragic illusion—the 'illusion of having solved the problem of production' [p. 13]. Schumacher used fossil fuels to illustrate the difference between capital and income, as well as to emphasize the importance of 'natural capital':

> First of all, and most obviously, there are the fossil fuels. No one, I am sure, will deny that we are treating them as income items although they are undeniably capital items. If we treated them as capital items, we should be concerned with conservation; we should do everything in our power to try and minimize their current rate of use; [but] ... far from being interested in studying the possibilities of alternative methods of production and patterns of living ... we happily talk of unlimited progress ... [p. 14].

Soil is the source of life—feed the soil, not the plant. Developing and maintaining soil quality with proper balances of organic matter, beneficial microbial and biological activity, and micro- and macronutrients has long

been a central activity and objective of organic farmers. Indeed, many argue that soil quality is the 'key' to long-term sustainable agriculture[9,23]. Organic farmers believed that synthetic chemical fertilizers and pesticides (and the monocultural cropping systems that these materials permit) disrupted these sensitive balances, thus requiring ever-larger applications of artificial compounds. There was also the widely held belief that food produced in artificially fertilized soils had less nutritive value, and was likely to have toxic pesticide residues that were linked to cancer, birth defects and various forms of antisocial behavior (such as crime), as well as psychological depression and hyperactivity, even gradual declines in mental acuity. Continued reliance on farm chemicals, it was alleged by some advocates of organic technologies, would lead to greater human suffering, more widespread illness, further declines in soil quality, and ultimately, the fall of modern civilization.

The organic ethic—additional precepts. Soil quality was the foundation that supported a number of additional core beliefs, not only about such matters as the proper way to structure a farm enterprise so as to optimize soil health, the health of farm crops and animals, and the health of those families who lived on the farm, but also about how to evolve appropriate values and lifestyles in keeping with the realities and limitations presented by Mother Nature. These wider concerns were critical parts of the total organic ethic or model.

According to Robert Rodale, organic ideology went beyond the simple matter of building and maintaining soil quality:

> Organic farmers and gardeners not only wish to avoid the use of many pesticides that can cause damage to wildlife, and create toxic effects in a variety of ways but they also are very much concerned about the prevention of erosion, the adding of humus and other organic matter to soil to improve fertility, the preservation of small family farms, localized marketing of food, energy conservation, and proper nutrition. It is a rare organic grower who does not share those concerns, or pursue those activities [p. 4][14].

The precept of anti-materialism—one of the pillars of organic ideology—appealed to a growing segment of the American public. The popularity of *Small is Beautiful* can be explained, in part, by Schumacher's eloquence in describing this issue. 'There can,' he said, 'be 'growth' towards a limited objective, but there cannot be unlimited, generalized growth' [p. 31][19]. Schumacher's economics of 'peace and permanence,' with its people-centered focus on anti-materialism, non violence, ecological sensitivity and conservation, appealed to organic farmers and their supporters. The ideology of making-do-with-less, or as one observer put it, 'living lightly on the earth'[24], captured much of what organic farmers believed in, and were trying to do.

Finally, the quest for a greater degree of independence formed a critical part of organic ideology. Many organic farmers found the growing specialization and interdependence of society's large organizations both repugnant and a threat to personal and national security. This belief fostered numerous features of the organic farming movement: local marketing cooperatives, it was argued, would help free people from large, impersonal, and interdependent marketing and distribution systems; better health, a by-product of eating organically grown food, would increase one's independence from a costly and sometimes indifferent healthcare system; the use of organic fertilizers and other on-farm resources would enable farmers to produce healthy crops with little or no reliance on the wasteful, expensive and unreliable petrochemical industry. Renewable sources of energy were sought for the same reasons. To be independent, Rodale explained, 'means that you have a basic liberty of existence ... The person who is truly independent will live well no matter what happens to the rest of society'[25].

Thus, organic ideology included not only a set of convictions about farming techniques and agronomic principles, but also ideas for how to live in a resource-constrained world. The failure of conventional agriculture to investigate the technology of modern organic farming, or to grasp the durability and widening appeal of its ideology, may help to explain how it could have so easily dismissed organic farming as being out of touch with the realities and requirements of contemporary American agriculture, not to mention the desires of a growing segment of American society.

Organic ideology: A two-edged sword

As organic farmers began to mobilize politically around the reassuring principles of their ideology (see below), conventional agriculturalists had begun to express a quite different set of reactions to the symbols and politics of organic farming. Many agricultural scientists and administrators, who were establishing professional careers and scientific reputations during the 1960s and 1970s, had been born and raised on farms much like those depicted in the expanding literature of organic agriculture. Memories of dawn-to-dusk work on these kinds of mixed crop–livestock farms collided with what they saw as little more than the romantic symbolism of organic farming. Armed with degrees from land-grant universities, schooled there in the latest scientific discoveries and engineering marvels, many agricultural scientists, understandably, were nonplused by the notion that these older, more diversified farm enterprise models deserved their support. Just as high technology was transforming other sectors of society, so too would it transform agriculture. The economic recession that began in 1974—and continued well into the 1980s—was widely attributed to the notion that the US had lost its competitive edge in high technology to Japan and West Germany. Instead of going back to an earlier farming model, US agriculture was being asked to help shore up America's technological competitiveness

through the expansion of research in such fields as biotechnology[26]. There were also concerns about agriculture's ability to maintain productivity gains, which were showing signs of leveling off[27]. For these and other reasons, the conventional agricultural community believed that the age of specialized, high-technology, high-yield agricultural production had arrived, just in time to meet the needs of expanding US and world populations. The admonition to American farmers from Secretary of Agriculture Earl Butz, to plant 'fence row to fence row'[28], was emblematic of the day's conventional ideology.

However, there was more to conventional agriculture's opposition to organic farming than these kinds of macroeconomic and technical issues. Many agricultural scientists educated during the 1960s and 1970s now held leadership positions within the agricultural research system, achievements gained, in part, from their own peer-reviewed research on the very same technologies now being criticized by (what appeared to be) non credentialed and overly zealous organic farmers, some of whom, it was believed, lacked previous farming experience or scientific training. Psychologically invested in the new technological paradigm, it was particularly difficult for such scientists and administrators to accept criticism from an agricultural constituency that, in their minds, simply lacked credibility. Moreover, the organic community's growing alignment with non agricultural constituencies (i.e., 'new agenda' groups favoring a liberal political agenda)—that had begun to seek access to scarce research dollars—made their demands all the more difficult to tolerate, or even comprehend.

Thus, the ideology that inspired and sustained organic farmers caused most within conventional agriculture to reject both the technology of organic farming, and its new agenda supporters. Had the ideology of organic farming been less powerful, less comprehensive, and perhaps less strident and uncompromising, it might have been less threatening to conventional agricultural scientists and other agricultural policy gatekeepers. Under these conditions, it is conceivable that conventional agriculture would have been more willing to explore the technology, *per se*, of organic farming (something scores of agricultural scientists would later do), as well as the ways in which these technologies might contribute to a more sustainable agriculture. However, as we learned some 50 years ago from Edelman[29], it is often the symbols—and not the reality—that guide our reactions to matters involving both public and private institutions.

Organic Agriculture Moves onto the Governmental Agenda

USDA's 1980 Report and Recommendations on Organic Farming

The organic farming community, in July 1980, received an unexpected boost from USDA with the release that month of its much anticipated *Report and Recommendations on Organic Farming*[9]. Since June 1979, the USDA Study Team on Organic Farming, assembled earlier that year by Secretary of Agriculture Robert Bergland, had quietly conducted the first-ever USDA-authorized investigation of organic agriculture in the US. (The Study Team's methods and findings are discussed below.) Although the Study Team, chaired by Agricultural Research Service (ARS) soil scientist Robert I. Papendick, had kept a low profile throughout its year-long investigation, the Team's activities had been closely monitored by both the conventional and organic agricultural communities. Once the Report was released, most analysts, including members of the Study Team itself, would characterize it as cautiously supportive of organic techniques. Others in both these communities would exhibit polar-opposite reactions. The organic farming community expressed surprise, relief and incredulity, finding it difficult to believe that a USDA study of organic farming would conclude that organic systems displayed a number of positive agronomic and conservation characteristics. The conventional community would also express surprise and disbelief, but certainly not relief—it reacted negatively to the Report, as well as to the very idea that such a study would have been sanctioned, funded and conducted by USDA[30,31].

These initial reactions to the Report would trigger an intensified debate, not only on the merits of organic farming but also on the consequences of conventional, chemical-based farming for the long-term sustainability of American agriculture. Ironically, the intensity of conventional agriculture's negative critique of the Report would prompt some leaders of the organic farming community to suggest that the word organic (which seemed especially repugnant to the conventional community) be replaced with such terms as biological, ecological, alternative, sustainable, practical, regenerative and even independent. This deliberate strategy of defending and advancing the principles of organic agriculture by introducing less threatening and in some cases more scientific-sounding words would have substantial, unintended consequences, not only for the evolution of organic farming over the next three decades but also for the larger debate about the future of American agriculture. This aspect of the history of organic agriculture will be considered later in this retrospective.

Secretary of Agriculture Bob Bergland. Nominated to be Secretary of Agriculture by President-elect Jimmy Carter in December 1976, Bob Bergland brought both political and farming experience to the Office of Secretary. He had operated a 640-acre grass seed and small grains farm near Roseau, Minnesota, most of his adult life, was elected to Congress in 1970 on the Democratic–Farmer–Labor Party ticket, and served four terms in Congress from Minnesota's northern 7th District. In the mold of a Midwestern, politically progressive, northern agricultural tier Democrat, Bergland had long championed the causes of ordinary workers and small-scale

farmers. Despite his politically progressive philosophical predilections, it would be a powerful yet somewhat unusual combination of issues and circumstances that led to Bergland's decision to launch a study of organic farming.

Bergland assumed the Office of Secretary at a time of severe financial stress and political turmoil in farm country. The newly formed American Agriculture Movement and other traditional general and commodity farm groups lobbied Bergland for increased government assistance to farmers in the wake of collapsing commodity prices. The dramatic tractorcades through the streets of Washington, DC, in the late 1970s dramatized the pain and frustration of many American farmers during this era's protracted farm crisis. Although much of the financial squeeze being felt by many of these farmers was the result of having borrowed heavily in prior years during a period of sharply higher prices—brought on by a series of crop failures and expanded exports—the reality of escalating fuel and fertilizer costs also played an important role in creating the cost-price squeeze of this period. While sharply higher energy prices, alone, may not have produced a financial crisis for America's farmers of the kind that developed in the late 1970s and 1980s, concerns over the cost and availability of energy needed to operate a conventional farm certainly were important and worrisome issues for farmers and farm policy makers.

Shortly after becoming Secretary, Bergland received the National Resources Inventory (NRI) report detailing a host of alarming problems and trends concerning the nation's soil and water resources on private lands[32]. This report served as a rallying cry for soil, water and wildlife groups throughout the country, who demanded that these natural resources issues be addressed more aggressively despite growing federal deficits and calls for restraints on government spending.

This would also be a period marked by heightened concerns over structural trends in US agriculture, particularly the continuing decline in numbers of mid-sized family farms, increasing concentration of land ownership, rising land prices, absentee farmland ownership, and degradation of soil and water resources (trends caused in part by incentives in commodity policy), and many other issues[33]. In response to these mounting concerns, in 1979 Bergland commissioned a formal review of US farm structure. The findings and recommendations of this review were published 2 years later[34].

While attempting to deal with these and other concerns, Bergland was reminded of the success of his neighbors back in Minnesota, Paul Billberg and his son Dale, who had been farming organically for some 6 years. The Billberg's 1500-acre farm included about 1000 acres of cash grains such as wheat and barley, and sizeable herds of cattle and sheep. Bergland was impressed by the Billberg's operation and likewise that Paul Billberg was 'a prominent, politically conservative farmer and active Farm Bureau member ... ' [p. 255][35]. When he returned to Washington, DC, after the Christmas holidays in 1978—which had included a lengthy visit with Billberg—Bergland asked his staff what the Department knew about organic agriculture. Upon learning that the Department had very little information, Bergland turned to Anson R. Bertrand, Director of USDA's Science and Education Administration (SEA), directing that he undertake immediately an investigation of organic farming in the US. Bergland wanted to know to what extent organic systems might help to address the environmental, structural and financial problems that were now plaguing American agriculture.

USDA Study Team on Organic Farming. As Director of SEA, a newly formed super agency designed to foster improved communication and coordination among USDA's science and education agencies, Bertrand had access to the Department's top scientists and policy analysts. Within weeks after receiving Bergland's directive, Bertrand had named Robert I. Papendick as chairman of the Study Team. Working with Bertrand, Papendick and other top-level SEA administrators moved quickly to name the remaining team members and make other administrative arrangements to undertake the study. At the initial team meeting in April 1979, held in James F. Parr's Biological Waste Management and Organic Resources Laboratory on the Agricultural Research Service (ARS) campus in Beltsville, MD, it was quickly agreed that the study would be conducted using the highest possible standards of scientific objectivity. (There would be no 'quick and dirty' treatment, as one SEA administrator had counseled.) Given the controversial nature of organic farming, there was considerable professional risk for those scientists who agreed to serve on this Study Team. Honing steadfastly to the canons of scientific research was the surest possible way for these scientists to avoid staining their respective reputations among their professional peers, as well as producing a credible research report.

Methods. Given the intense criticism of the Report's findings and recommendations from the conventional agricultural community (discussed below), it is important to briefly review the methods used by the Study Team in gathering and assessing the data. The following summary of the methods used relies heavily upon the Report's own words [pp. 3–5][9].

On-Farm Interviews. Credible information on organic farming in 1979 was quite limited. Thus, to gain an overall understanding of the latest organic farming technologies, levels of economic success, and factors affecting the adoption and productivity of organic systems throughout the US, the Study Team elected to conduct a series of on-farm case studies. Ultimately, 69 such case studies were conducted, some in each of the ten US agricultural production regions, using a standard interview schedule. Because there was no national database of organic farmers available in 1979, the farms were selected through contacts at '[l]and-grant universities, the State Cooperative Extension Service, organic producer associations, publishers of organic literature, and commercial

companies that deal with organic growers [p. 3][9]. According to the Report:

> Information was obtained on the background and attitudes of the farmers, farm composition, soil resources, types of crops and livestock grown, crop sequences, tillage methods, production inputs and management practices, and marketing procedures. During each interview, visual observations were made of crop conditions, including stands, growth, and degree of weed and insect infestations [p. 3][9].

Survey of New Farm *Subscribers.* During the data collection process, Rodale Press provided the Study Team with the results of its survey of subscribers to *The New Farm* magazine. This survey, sent to 1000 randomly selected subscribers, yielded a 70% response rate. Respondents self-identified as 'conventional' (112), 'organic' (95) and 'combination conventional-organic' (204) farmers; those remaining were nonfarmers. Information generated by this survey, which was similar to the Study Team's on-farm interview schedule, provided valuable comparative and contextual data.

Literature Review. The Study Team conducted a comprehensive review of the scientific, economic and sociological literature pertaining to organic agriculture. Information gathered through this process helped the Team to not only assess the contemporary character of organic farming but also to place its current status in historical perspective.

Organic Farming in Europe and Japan. To assess the scientific and practical status of organic agriculture in Europe, where interest in organic farming appeared to be growing rapidly, four Study Team members toured research facilities in Germany and Switzerland, as well as a number of organic farms and organic food processors, and one farm-implement manufacturer specializing in machinery for organic production. One team member spent time in Japan touring organic farms and studying the production and marketing of organically grown fruits and vegetables.

Findings and recommendations. Some 30 years after its publication, it may be difficult for those reading the Report today to understand why its findings and recommendations would have caused such a commotion within agricultural circles. Within the context of today's organic agriculture world, the Report's principle findings may seem unremarkable, its recommendations quite reasonable, even restrained. Findings (such as the fact that organic farming can be practiced on large acreages) have now been well documented and are no longer disputed. Many of the recommendations (such as the call for holistic, systems-oriented research) are now part of the standard organic agriculture research lexicon. Indeed, except for the more historically oriented or those old enough to have either observed these events or directly participated in them, the Report overall has been somewhat forgotten or simply overlooked. The 2010 National Research Council (NRC) report[36] on sustainable agriculture, for example, which includes information not only on organic farming but also on other subjects (such as mixed farming systems) covered in the 1980 Report, fails to mention the prior study. The literature dealing with organic farming and its underlying principles has simply exploded over the past 30 years, albeit most of it under the rubric of sustainable agriculture. Astonishingly, the NRC report includes some 68 pages of references, roughly two-thirds as many pages as comprised the 1980 Report in total.

Before exploring the Report's controversial history, we summarize its major findings and recommendations. (The full report is online at http://www.nal.usda.gov/afsic/pubs/USDAOrgFarmRpt.pdf.) The Report's summary briefly describes 12 major findings [pp. xii–xiii][9] that are here condensed and collapsed into eight.

(1) Organic farmers fall along a spectrum from the utterly pure (i.e., those who would not use any chemical fertilizers or pesticides under any circumstances) to those who would use these materials, especially synthetic fertilizer, but only infrequently and sparingly as a last resort. Regardless of where they fell along this continuum, these respondents considered themselves to be organic farmers.

(2) The vast majority of organic farmers had not regressed to the farming practices and technologies of the 1930s, nor were these operations limited by scale. Among the 69 case study farms, respondents were using 'modern farm machinery, recommended crop varieties, certified seed, sound methods of organic waste management, and recommended soil and water conservation practices' [p. xii]. The scale of operations included some farms, especially in the Northeast, of only several acres, and some, especially in the heartland, ranging from 100 to as high as 1500 acres. Regardless of size, the farms in the survey were 'productive, efficient, and well managed' [p. xii]. Some of the larger-scale farmers had switched from chemical to organic practices.

(3) Study respondents expressed a range of motivations for electing to farm organically. These included: '... concern for protecting soil, human, and animal health from the potential hazards of pesticides; the desire for lower production inputs; [and] concern for the environment and protection of soil resources' [p. xii].

(4) Most of the surveyed farms fell within the broad parameters of mixed crop/livestock operations. Legumes and other cover crops were rotated with various cash crops such as corn, wheat or soybeans, depending upon geographic location. Animals comprised an essential component of the overall farm enterprise, with substantial amounts of grain and hay crops fed to animals on the farm, then recycled back onto the land as manure. In most cases, this system produced enough nitrogen (N) and other nutrients for crop yields acceptable to the farmer. The Study Team was impressed by the ability of these types of systems 'to

control weeds in crops such as corn, soybeans, and cereals without the use (or with only minimal use) of herbicides ... [and instead with] timely tillage and cultivation, delayed planting, and crop rotations' [p. xiii].

(5) Some of the respondents complained about the lack of interest in their operations from USDA and their respective land-grant universities, and the lack of technical information available from these institutions.

(6) Although the Study Team was generally impressed with the management, production levels, economic performance and conservation characteristics found on most of the survey's 69 farms, it did conclude that some of these farms were probably 'mining' residual supplies of potassium (K) and phosphorus (P), and that at some point these operations would be forced to supplement these two nutrients.

(7) Farm labor requirements, energy use, and net economic returns are important variables used to assess total farm performance. On these measures, the Study Team found that these 69 organic farms, on balance, required somewhat more labor, but used less energy, than conventional farms. The economic models developed by the Team 'showed that the economic return above variable costs was greater for conventional farms (corn and soybeans) than for several crop rotations grown on organic farms' [p. xiii]. The need to devote a large portion of the acreage on organic farms to legumes and other green manure crops largely accounted for these findings.

(8) The Study Team concluded its summary of major findings with the following statement: 'There are detrimental aspects of conventional production, such as soil erosion and sedimentation, depleted nutrient reserves, water pollution from runoff of fertilizers and pesticides, and possible decline of soil productivity. If costs of these factors are considered, then cost comparisons between conventional (that is, chemical-intensive) crop production and organic systems may be somewhat different in areas where these problems occur' [p. xiii].

Clearly, these findings and conclusions lent official governmental legitimacy to the proposition that organic farming systems exhibited an impressive assortment of positive agronomic and environmental characteristics, and therefore were deserving of increased support from USDA and the land-grant university system. It was this new reality, this aspect of the Report, which drew the most attention, and generated the most heated reactions, from within conventional agricultural institutions and interests, both public and private. Within this political context, the Report's research, education, extension and policy recommendations, though important, failed to achieve a correspondingly high level of attention and scrutiny.

As the likelihood of USDA support, including additional new funding, quickly waned under the Reagan Administration (see below), there was little incentive, initially, for agricultural scientists and educators to embrace these recommendations or to begin formulating new programs. In retrospect, however, we can see how many of the Report's recommendations [pp. 86–94][9] have become important elements of contemporary organic research, education and extension activities. The Report's call for holistic, interdisciplinary research; study of the transition from conventional to organic systems; research on nutrient cycling for crop production, soil improvement through enhanced utilization of organic wastes, biological weed, insect and disease control, and biological nitrogen fixation; development of crop varieties adaptable to organic systems; and many of its other recommendations, continue to be among those critical research questions and challenges facing today's organic investigators and educators (e.g., see Sooby et al.[37] and Francis[38]).

Finally, the Study Team reported the following most frequently cited concerns by farmers and the general public regarding the extensive and sometimes excessive use of chemical fertilizers and pesticides, and the large energy inputs required of conventional agricultural systems [p. xi]:

- Increased cost and uncertain availability of energy and chemicals.
- Increased resistance of weeds and insects to pesticides.
- Decline in soil productivity from erosion and accompanying loss of organic matter and plant nutrients.
- Pollution of surface waters with agricultural chemicals and sediment.
- Destruction of wildlife, bees and beneficial insects by pesticides.
- Hazards to human and animal health from pesticides and feed additives.
- Detrimental effects of agricultural chemicals on food quality.
- Depletion of finite reserves of concentrated plant nutrients, for example, phosphate rock.
- Decrease in numbers of farms, particularly family-type farms, and disappearance of localized and direct marketing systems [pp. 1–2][9].

Organic farming defined. The definition of organic farming developed by the Study Team arose directly out of the empirical findings and observations gleaned during the course of the study. The Team had no preconceived notion of how to define organic farming. It was aware, however, that for marketing purposes, formal definitions existed in several states, most notably Maine and California, and that a number of other state and regional organic producer associations were in the process of developing formal definitions. Since many of the respondents in the USDA study would not have qualified as organic under these definitions (but, nonetheless considered themselves to be organic farmers), the Study Team developed a less-than-pure definition that simply reflected the spectrum of practices actually found on the 69 survey

farms. Thus, for purposes of the 1980 Report, the following definition was used:

> Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests [p. 9][9].

This less-strict definition was never intended to serve as a guide for certification and marketing of organic foods. It was intended to reflect the essential agronomic components and characteristics of organic farming technology discovered over the course of the survey. The Department's principle motivation was to learn as much as possible about how organic practices might be incorporated into conventional agricultural production systems as a means to help alleviate some of the problems that had begun to plague American agriculture (such as soil erosion, water pollution and increasing energy costs), not to address directly the needs of the organic certification process.

There is, in fact, nothing in the Report's definition of organic farming, its research results or commentary, or in the Recommendations for Action [pp. 86–94][9], to imply that agricultural chemicals should be completely eliminated from American agriculture. To the contrary, the specific language of the Report, as well as its overall tone, suggests a quite different and much broader agenda: restoring balance and choice to American agriculture. Nonetheless, in the Study Team's view, if achieving organic certification appealed to certain segments of the farming population, those farmers deserved a reasonable measure of technical assistance and research support from USDA and the land-grant universities. As one top USDA administrator who had originally opposed the organic farming study would later say in its defense: 'Organic farmers pay taxes, too.'

The immediate aftermath. The Department's rationale for following up on the Report failed to reassure its detractors, particularly many federal agricultural agency research leaders, land-grant university scientists and administrators, and personnel of private firms involved in the manufacture and sale of agricultural chemicals. As late as 1984, long after some members of the conventional agricultural community had begun to understand and accept the potential benefits of at least some aspects of organic farming, the remarks of Terry B. Kinney, administrator of USDA's Agricultural Research Service, reflected how dismissive of organic agriculture many within conventional agricultural circles continued to be. When asked by a reporter about the 1980 USDA organic farming report, Kinney replied: 'What do you mean by organic farming? I refuse to think about organic farming *per se*. I grew up on a farm, and I know what wormy apples and corn decimated by bugs are like'[39].

With the election of Ronald Reagan in November 1980 (4 months after the Report's release) and the appointment of John Block, a large-scale hog and grain farmer from Illinois, as Secretary of Agriculture, those who opposed the Report—and the Department's fledgling organic program—had acquired a powerful political ally. Within months after taking office, Secretary Block assured conventional agriculture that there would be no follow-up to the previous administration's 'dead end' organic farming initiative[30]. In the spring of 1981, the Department's newly designated Organic Farming Coordinator was told to spend only half his time on follow-up activities related to the 1980 Report. The Coordinator position would be eliminated a year later as part of a Reduction in Force.

These reactions stood in stark contrast to those of organic farmers, other elements of the new agricultural agenda, the farm, science, and general press, substantial numbers of agricultural scientists, and a small contingent of members of Congress. These and other observers viewed the Report as a reasonable and measured attempt to learn how organic farming systems worked, and how these practices might be brought to bear on the problems of US and world agriculture. They did not perceive the Report as representing a wholesale assault on conventional agriculture.

A review of the Report in the July 11, 1980, issue of *Science* magazine—several days before its official release—reflected these typically moderate reactions. Luther J. Carter, author of the *Science* article, was quick to point out, for example, that the Report did 'not suggest that a sweeping conversion of farmers to organic methods is either likely or desirable. But it suggests that many farmers can, and perhaps should, adopt organic farming practices, combining them with conventional practices if necessary or desired' [p. 254][35]. According to Carter, Secretary Bergland had told *Science*: 'We think it is an important report—the first recent report to look at organic farming as a legitimate and promising technique ... We now depend on imported oil and exported wheat, and farmers are worried about these forces over which they have no control. People are looking for ways to reduce their fuel-related inputs' [p. 254][35]. The USDA Report had specifically recommended research on various combinations of conventional and organic practices in order to reduce chemical/energy inputs in US agricultural production systems [p. 92][9].

Certainly, reducing the use of these inputs was a major factor motivating Bergland's neighbors, Paul and Dale Billberg, who told Carter they had lowered their fertilizer costs by switching to legume-based rotations, and by adopting shallow tillage methods instead of using the more energy-intensive mold board plow that inverts the soil profile, requires more tractor fuel, and

depletes soil organic matter through increased oxidation and erosion. 'The life and tilth of the soil were just not there any more,' said Dale Billberg [p. 254][35]. The Billbergs also insisted that since adopting organic methods their animals were healthier and their veterinary bills were reduced.

Carter's review concluded with these words: 'Farmers tend to be set in their ways, but when there is as much trouble down on the farm as there is today, they can be amenable to change. Many may soon be taking a look at organic farming practices that can perhaps ease some of their problems, such as loss of topsoil to erosion and loss of income to escalating fertilizer costs' [p. 256][35].

Although the USDA Report may have fallen on hard times within the Department that produced it, the message it conveyed could not easily be contained. Within 2 years the Report was translated into seven foreign languages, and thousands of individuals and organizations were requesting copies. Its impact spread quickly to Capitol Hill, academia, dozens of grassroots organic producer and advocacy organizations, international forums, and a plethora of Washington, DC-based environmental, food safety, nutrition, wildlife, social justice and rural development groups (all elements of the new agricultural agenda coalition) that would, for the first time, take up the banner of organic agriculture. These new agenda groups championed organic agriculture with legislative initiatives, symposia, in-house studies and reports, on-farm demonstrations, and many other research and education outreach programs. Many in the print and broadcast media would continue to report on shifting attitudes among farmers, scientists and legislators.

There also would be scores of scientific conferences and symposia devoted to extensive and detailed examinations of the character and implications of organic farming and its potential role in a sustainable agriculture. Many colleges and universities established special courses and curricula (a few even created prestigious faculty chairs and centers) devoted to the exploration of organic methods and principles[40,41]. Most of these initiatives, however, for reasons discussed below, were labeled 'sustainable' by the end of the 1980s.

The Report's impact and life cycle

The 1980 USDA Report was a precipitating event for many of these developments, not the only causal factor. With or without it, the Zeitgeist of the era likely would have caused many of these changes to have evolved in some form. While the Report may have provided support for some new agenda demands, it did not create those demands; nor did it create the organic farming movement. Similarly, the problems and concerns associated with conventional agriculture, while noted in the Report, certainly were not caused by it. Clearly, however, the USDA imprimatur on the 1980 Report did help to catalyze, encourage and strengthen many of these initiatives.

For the new agenda groups, other reformers and a growing number of agricultural scientists (especially those trained in the more traditional agronomic sciences, as contrasted with the newer agricultural science fields of biochemistry, molecular and cell biology, and biotechnology[26]), the Report provided the outlines of a positive alternative agricultural model. Opponents and skeptics of conventional agriculture were no longer placed in the awkward position of simply criticizing conventional technologies, they could now mobilize around the findings and recommendations of the Report, and do so with an added measure of knowledge, confidence and legitimacy. A commentary in *Countryside* magazine in October 1980 seemed to reflect this new-found hope: '... [I]n view of the ideas and insights of the USDA report, one cannot help being more optimistic that, as U.S. agriculture seeks to solve its problems of soil depletion and excessive chemical use, it will turn to the answers offered by organic agriculture as a means of building a sustainable agriculture'[42].

In fact, pro-organic groups initially would rely heavily upon the USDA Report for ideas, and as a source for scientific legitimacy in support of their policy proposals. Over the next several years, however, its influence waned. Countless new reports and scientific conference proceedings, even several new peer-reviewed journals, would provide credible, more current and much more diverse sources of information in support of these policy activities. The substitution of the word sustainable—in place of the word organic—over the decade of the 1980s also would hasten the Report's declining visibility and influence. Even those scientists and policy makers who felt comfortable using the word organic could no longer ignore the liabilities of its negative scientific and political symbolism. Finally, the definition of organic agriculture set forth in the Organic Foods Production Act of 1990 (and implemented in 2002, see below) effectively denied any use of the word organic except for the purposes set forth in that legislation. Once the word organic had been legally defined in federal law (to facilitate and encourage the marketing of organically grown food), its continued use as a descriptive term for the more general agronomic and environmental meanings and purposes discussed in the USDA Report would have been disruptive and confusing. Thus, by the end of the decade, the 1980 Report would be eclipsed by these multiple developments and the new language they fostered. Despite its declining role, many of the activities highlighted below—for the most part, under the banner of sustainability—continued to reflect elements of the Report's findings and recommendations, not to mention the ideology of organic agriculture.

Sustainable Agriculture: Interest Group Strategies in an Altered Policy Environment

As noted previously, from the moment the 1980 USDA Report on organic farming was released there were

indications that the word organic would constitute an important barrier to acceptance of the Report's findings and recommendations, particularly within USDA, the land-grant university system, and among many private-sector conventional agricultural leaders and organizations. One need only trace the public evolution of the word organic in order to gauge how conventional agriculture's aversion to the word itself, to the 1980 Report, and to organic farming generally, affected conventional agricultural science, Capitol Hill and the organic farming community.

At about this time, coincidentally, the word sustainable would begin to emerge in both popular and scientific literature as the word of choice for denoting the most critical, overriding goal for US and world agriculture, especially among those groups and individuals who contended that conventional systems were not sustainable. Many attribute the formal emergence of this term within the context of contemporary agriculture to its use by Wes Jackson in his 1980 book, *New Roots for Agriculture*[43], and even earlier to arguments presented in his less well-known 1978 essay, 'Toward a Sustainable Agriculture'[44].

In response to conventional agriculture's negative and increasingly shrill critique of organic farming, and to the USDA's 1980 Report, organic advocates quickly seized upon the word sustainable as a means of defending and promoting the value of modern organic systems. Associating the goal of sustainability with organic farming, and likewise the 1980 Report, was seen as a way of imbuing both with a modern, more scientific, and more urgent purpose and image, thereby countering the negative symbolism of the word organic for conventional farmers, scientists and policy makers (Eliot Coleman, personal communication, December 2010). It should be noted, however, that the goal of sustainability has long been an important element of organic ideology. Lord Northbourne, for example, considered by many to have first used the term 'organic farming' in his 1940 book, *Look to the Land*[45], envisioned 'the farm as a sustainable, ecologically stable, self-contained unit ... ' [p. 1][46]. His concerns, according to Scofield, including soil erosion, soil health, 'the exhaustible nature of imported fertility,' and human health, remain part of the debate over agricultural sustainability [pp. 1–2][46].

Within conventional agricultural research circles, those scientists sympathetic to organic farming systems also would soon resort to use of the word sustainable as a strategy for legitimizing the investigation of organic technologies. The first major scientific exploration of organic farming following release of the 1980 Report took place in 1981 at the annual meeting of the American Society of Agronomy. This full-day symposium, sponsored by the Soil Microbiology and Biochemistry division of the Soil Science Society of America, was entitled 'Organic Farming: Current Technology and Its Role in a Sustainable Agriculture.' The agonizing search for language acceptable to conventional scientists appears in the Preliminary Program. The organizers spoke of 'the need to make Society members aware of ongoing research in the area [of organic farming] and the possibilities of amalgamating high energy input agriculture with low energy input agriculture to provide sustainable cropping systems'[47]. The symposium was timely, according to the organizers, because of the potential of organic farming to lower energy inputs and develop a sustainable farming system.

Over the next several years the word organic would virtually disappear from scientific conferences dealing with sustainable agriculture. In 1988, for example, a major two-day conference at Ohio State University (OSU), entitled 'Sustainable Agricultural Systems,' would fail to include the word organic in material justifying the conference, or in the titles of any of the 40 formal presentations. This, despite the fact that the Preface to the published proceedings would use these words to help explain the importance of the conference:

> There is a growing awareness about the need to adopt more sustainable and integrated systems of agricultural production that depend less on chemical and other energy-based inputs. Such systems can often maintain yields, lower the cost of inputs, increase farm profits, and reduce ecological problems [p. xiii][48].

Clearly, by the late 1980s, the scientific community had largely abandoned the word organic, even though the actual technologies under consideration at this conference and other similar events included techniques and systems long associated with organic farming. At the OSU conference, nutrient cycling was presented as a key element of a sustainable agriculture. In the USDA's 1980 Report, nutrient cycling was seen as a key feature of organic systems. In less than a decade, sustainable agriculture had become the linguistic repository not only of agriculture's long-term goals but also of the technologies needed to achieve those goals as well.

A somewhat different (but no less revealing) example of efforts to find substitute language for organic technologies which was acceptable to both political and scientific audiences occurred within USDA. In a July 1981 memo from Anson R. Bertrand, Director of USDA's SEA, to the Department's Organic Farming Coordinating Committee, we find these words: 'Since the USDA Report and Recommendations on Organic Farming was published in July of 1980, *interest in low energy-biological farming systems continues* [emphasis added]'[49]. Within the Department, signals from Secretary Block and other opponents of organic farming had successfully stifled use of the word organic, but not necessarily its ideology and technology.

The chilling effects of USDA's attitude toward organic farming would ripple through some parts of the nonprofit sector as well. In Iowa in 1985, for example, a group of organically oriented farmers, as well as some farmers

simply searching for ways to survive the financial crunch of the 1980s farm crisis, would organize a small producer organization that they chose to call The Practical Farmers of Iowa (PFI). The group's organizers were primarily interested in learning more about how organic-type methods and other low-chemical approaches could help reduce input costs, improve net farm income, and begin to address the growing issues of soil and water quality in Iowa and throughout much of the Midwest. The group's organizers reasoned that researchers at Iowa State University (ISU) might feel comfortable working on 'practical' solutions to these and other problems, thus avoiding the potentially divisive politics and symbolism of such words as organic and sustainable. PFI has been remarkably successful, its field days and on-farm co-operative research with ISU attracting national and international attention. Given the anti-organic ideology of conventional agriculture during the early 1980s, the decision of these farmers to be 'practical' would seem to have produced enormous dividends. There is, of course, no way of knowing how this group's history might have evolved with the word organic in its name.

Clearly, disputes over the symbolic uses and meanings of language have greatly influenced the history of organic agriculture in the US, especially in the more than three decades since publication of the 1980 USDA Report. Nowhere is this more evident than in the history of congressional efforts to craft legislation supportive of organic farming.

Capitol Hill and organic farming: The early push for legislation

Led by Representative Jim Weaver of Oregon and Senator Patrick Leahy of Vermont, a small contingent of Congresspersons responded quickly to the legislative opportunities created by the 1980 USDA Report on organic farming. Initially, these supporters took steps to ensure the inclusion of organic farming language in the 1981 Farm Bill. That language called for establishing 'integrated multidisciplinary organic farming research projects designed to foster the implementation of major recommendations of the US Department of Agriculture's *Report and Recommendations on Organic Farming*, July 1980'[50].

The following February, Weaver introduced his initial organic farming bill, the Organic Farming Act of 1982 (H.R. 5618)[51]. Weaver hoped his bill would become the legislative vehicle for implementing the authorizing language included in the 1981 Farm Bill. According to Weaver, expanded research on organic farming was justified by 'the skyrocketing cost of energy, petro-chemically-based fertilizers, and pesticides. More importantly, there is a growing concern about the dramatic soil erosion and nutrient depletion often associated with many conventional farming practices'[52]. Weaver's bill required the Secretary of Agriculture to 'establish 6 pilot projects, taking into consideration the *Report and Recommendations on Organic Farming*, United States Department of Agriculture (July 1980) ...' (H.R. 5618, Sec. 4, (a))[51]. These pilot projects were to develop science-based information on a range of organic farming methods such as crop rotations, green manures, and other technologies and management techniques needed 'in making the transition from conventional chemical-intensive methods of farming to methods of organic farming' [H.R. 5618, Sec. 4, (a) (1) & (2)][51].

In April 1982, Senator Leahy introduced companion legislation in the US Senate. After months of internal staff debate, Leahy opted to call his bill the Innovative Farming Act of 1982 (S. 2485)[53]. The Senator and his staff had concluded that using the word organic in the title would not only have guaranteed the bill's defeat, but denied it a fair hearing as well. With the exception of a different title, however, Leahy's bill mirrored the Weaver legislation, defining organic farming precisely in the same way it had been defined in the 1980 USDA Report. Despite the bill's 'innovative' title, the purpose of Leahy's legislation was clear. The USDA opposed this legislation[54,55], and neither bill would pass.

These defeats marked the beginning of a 7-year hiatus in early congressional efforts to advance organic farming legislation using the word organic. Not until 1989, when Senator Leahy introduced a bill dealing with a national certification program for marketing organic products (see below), would the word organic headline any congressional legislation. The search for more creative language to advance organic methods would now challenge the supporters of organic agriculture on Capitol Hill.

The political landscape: New (organic) realities

By 1983, 3 years after publication of USDA's organic farming report, political reality had replaced the climate of optimism among organic farmers and the new agenda groups which had accompanied its release. While the agricultural community could no longer ignore the negative externalities of conventional agricultural production practices, or the early 1980s groundswell of accelerating demands for changes in food, agriculture and environmental policy—circumstances that might have opened new pathways for promotion and use of organic methods—opposition to organic farming from conventional agriculture and the Reagan Administration was unyielding. Despite accumulating evidence of ground and surface water contamination from agricultural chemicals[56,57], increased levels of soil erosion and declines in soil productivity[58–60], adverse effects of technology and farm policy on trends in farm structure[61], increasing pest resistance to pesticides[62], links between human illness and routine use of antibiotics in animal feed[63], rising energy prices, and the continuing severity of the farm economic crisis, Secretary Block's USDA could see no role for organic farming in American agriculture.

Instead, the conventional agricultural community insisted that these issues were being addressed through modification of existing technologies, and development and adoption of new ones. Biotechnology, precision agriculture, conservation tillage, improved soil tests, integrated pest management (IPM), best management practices (BMPs) and better ways to handle environmental threats from CAFOs were among the solutions offered by conventional agriculture. The Administration, agribusiness, most farmers and most agricultural scientists appeared to be solidly in agreement with this set of prescriptions. By 1983 the organic community had come to realize that it would need a new legislative strategy if it hoped to include its voice and its technologies in the national debate over the future of US agricultural policy.

Against this backdrop, in the spring of 1983, Weaver and Leahy jointly introduced the Agricultural Productivity Act of 1983 (H.R. 2714[64]; S. 1128[65]), legislation that called for a number of familiar-sounding, organic-type program initiatives. While the word organic was conspicuously absent in this legislation, it nonetheless authorized twelve 5-year-long on-farm studies 'for the purpose of examining the effects of the transition from—(A) farm practices which rely on synthetically compounded fertilizers, pesticides, growth regulators, livestock feed additives, and tillage practices which fail to control erosion; to (B) farm systems which rely on legume and other sod based rotations, the efficient use of crop residues, green manures, off-farm organic wastes and ... nonchemical or biological methods of weed and pest control' [H.R. 2714, Sec. 5, (a)][64]. Both bills also called for data collection on 12 farms that had used alternative systems for five or more years. Other provisions authorized cost-share payments for intercropping of legumes, and directed USDA to assess the availability of extension materials related to alternative methods and to recommend research that would help farmers better understand low-energy farming methods. Sponsors and supporters were cautiously optimistic about the prospects for passage of this creatively worded organic legislation.

An August 3rd House subcommittee hearing on H.R. 2714, chaired by Rep. Weaver, reinforced this sense of optimism: the only formal testimony in opposition to the bill came from USDA. According to Clare Harris, Acting Administrator of Cooperative State Research Service, the Department was 'sympathetic to the purposes' of the legislation, but could not support it because 'much of this work is currently underway; the bill would impose overly restrictive requirements on the conduct of such research and the costs are excessive' [p. 48][66]. This would be the Department's essential argument against the bill, and other later versions, for the next several years.

Witnesses testifying in favor of H.R. 2714 gave a variety of predictable reasons for supporting the bill. However, the testimony of Patrick Madden, the Penn State agricultural economist who 5 years later would become the first coordinator of USDA's Low-Input Sustainable Agriculture (LISA) program, seems especially telling. Madden called the bill's objectives 'admirable, well worth pursuing, and attainable' [p. 78][67], which he had prefaced by the following: 'I am pleased that the term organic farming does not appear in the act, because the term is laden with emotional content that gets in the way of useful discussions and actions' [p. 76].

That a prominent supporter of organic farming would publicly acknowledge that the word organic had itself become an obstacle to progress on low-input farming illustrated just how sharply the political climate surrounding organic agriculture had deteriorated in just 3 years. What was not known in 1983, however, was that any national policy effort designed to support the investigation of organic technologies—regardless of the language used—would be met with determined opposition from various elements of the conventional agriculture community, including major input suppliers and commodity organizations[55] [pp. 140–146][68]. This pattern can be seen in the legislative and administrative history of the USDA's LISA program, authorized in the 1985 Farm Bill, as well as in the Sustainable Agriculture Research and Education (SARE) program, authorized in the 1990 Farm Bill[69], and in the controversy surrounding a major NRC report released in 1989, entitled *Alternative Agriculture*[70].

With respect to the Agricultural Productivity Act itself, opponents of this legislation would hold it in abeyance until 1985 when some of its features were incorporated into the 1985 Farm Bill in Subtitle C, Title XIV, as 'Agricultural Productivity Research'[71]. It would be three more years before any funds were appropriated to implement this provision as USDA's LISA program. By then, some 8 years would have elapsed since release of the 1980 USDA Report on organic farming, the initial impetus for this protracted legislative effort. The word organic was not included in Subtitle C, and the LISA appropriation in 1988 was for a mere $3.9 million, a tiny fraction of total federal agricultural research funding. Still, most supporters of organic/sustainable/low-input farming considered LISA a noteworthy step in the right direction. They were already planning for the 1990 Farm Bill fight, the next major legislative opportunity to advance what many were now calling sustainable agriculture.

Organic/sustainable agriculture in the 1990 Farm Bill

As preparations for the 1990 Farm Bill began, organic producer and certification associations, along with the quickly expanding organic wholesale, retail, processing and distribution industries, were focused on the creation of a national certification program for organic foods and other products. The Organic Foods Production Act (OFPA) (S. 2108)[72], introduced by Senator Leahy in early 1990, provided for establishing a USDA 'organically produced' label for products meeting a strict set of national standards and guidelines. As Leahy said when

this legislation was initially introduced in late 1989 (S. 1896)[73]: 'Since goods labeled organic often sell at premium prices, the temptation to misuse the word is great ... A national organic certification program will ease problems in interstate commerce' and 'give farmers a commercial incentive to alter the way they farm'[74]. Not since 1982 had national legislation dealing with organic farming actually used the word organic to denote its character and purposes. To avoid consumer confusion, the bill prohibited all other uses of the word organic. Ultimately, the OFPA became part of the 1990 Farm Bill; however, disputes between the organic industry and USDA, and disagreements within the industry itself over the meaning of specific provisions of the bill, would delay its implementation until 2002 (see the following section on Organic Certification).

Meanwhile, as use of the word organic shifted toward legally defined, commercial purposes, other supporters of organic technologies had begun to use words such as sustainable, alternative and low-input when promoting the use of organic methods to address issues such as soil erosion and water quality, and to lower farm production costs. Groups supporting organic-type technologies for these more traditional purposes had reason to be optimistic as the 1990 Farm Bill rolled into view. Bolstered by the growing popularity of the 2-year-old LISA program (LISA had faced strong opposition from agribusiness and some land-grant university scientists and administrators during its startup phase[69]), its supporters were determined to broaden and refine its scope and impact. Since passage of the 1985 Farm Bill with its historic swampbuster, sodbuster, conservation compliance and conservation reserve measures[75], a number of new ideas for incorporating various organic-type methods (such as crop rotations) into conservation and commodity policy had been advanced, some in the form of legislative proposals[76,77]. Moreover, since passage of the 1985 Farm Bill, there had been a constant flow of articles and reports documenting the need for a more environmentally sound agriculture, as well as evidence that low-input methods could contribute to the goal of sustainability.

When the 1990 Farm Bill[78] had (finally) passed both houses of Congress, sustainable agriculture supporters were pleased—although not entirely—with the results. Those who had fought for the expansion of programs featuring organic-type technologies could point to the following successes. The LISA program had been reauthorized, along with a companion federal-state matching grant program to help states expand sustainable agriculture. Additional authorization was included for extension agent training and development of technical publications designed to help farmers adopt sustainable practices. The Bill also authorized research on 'integrated management systems' aimed at developing environmentally sound crop and livestock systems.

Beyond these research and education provisions, the 1990 Farm Bill allowed farmers, for the first time, to plant environmentally beneficial, nonprogram crops on up to 25% of their commodity crop base acres, without losing any of the farm's historic commodity crop base. Also, a pilot Integrated Farm Management Program Option was included under which farm program participants could develop 3- to 5-year sustainable farm plans that authorized planting of resource-conserving crops on their commodity base acres, as well as the right to use a portion of that set aside for commercial haying or livestock grazing. Calls for incorporating these kinds of flexible, environmentally friendly practices into commodity policy had been a major goal of organic and sustainable agriculture advocates for many years.

Sustainable agriculture and public policy: Competing definitions and agendas

Yet despite these noteworthy organic/sustainable agriculture policy accomplishments (as outlined above), close observers of the 1990 Farm Bill process had reason to be concerned. Within the Bill's overall context, with exception of the organic certification measure, these policy gains could best be described as marginal: most traditional agricultural research priorities and price support policy remained in place, and some within the low-input, sustainable agriculture community were beginning to wonder if use of the word sustainable for advancing organic-type technologies had begun to backfire. As the Farm Bill debates unfolded, it had become increasingly clear that multiple definitions of sustainable agriculture had confused and frustrated lawmakers. Early efforts by Representative George E. Brown, Jr, Chairman of the Research Subcommittee of the House Agriculture Committee, and many others, to make the low-input, organic-type version of sustainability the overarching organizing principle of the 1990 Farm Bill[79] had fallen far short of expectations. Brown's notions of sustainable agriculture would have to compete with those of USDA and agribusiness. By 1990, conventional agriculture had staked a firm claim on its own version of the symbolically powerful notion of sustainability.

Throughout the debates on the 1990 Farm Bill, sustainable agriculture became a political football on the largest stage in agricultural policy. Groups that would have been urging adoption of organic policy options 10 years earlier were now using the word sustainable to push in that direction. Meanwhile, other elements of the organic community seemed poised to create a popular and highly visible national certification program for organically grown food and other products. While this initiative may have seemed misguided and somewhat threatening to conventional agricultural interests, these traditional policy gatekeepers simply could not allow the organic community to claim sole ownership of 'sustainability,' a term laden with implications for the future of US agricultural policy. This struggle for control of the symbolic uses of sustainability for political purposes was not new,

its broad outlines had been evolving throughout the 1980s. The 1990 Farm Bill debates simply provided a public venue for exposing how this issue would play out in the face of specific policy disputes, not merely in symposia and conferences—settings where sustainable agriculture had often provided the language needed to gloss over policy differences, and seemingly reduce tensions, between conventional and organic communities.

The 1990 Farm Bill debates over how best to define sustainable agriculture were not new. The history of agriculture includes many thoughtful perspectives offering valuable insights and guidance for understanding the importance of sustainability and addressing its multifaceted characteristics[80–82]. While these commentaries have a long, important history, growing signs of agriculturally induced environmental degradation and rapid changes in farm structure—trends that had become increasingly evident by the late 1970s—made the search for more precise definitions of agricultural sustainability, and better understanding of its parameters and requirements, seem increasingly urgent. Over the past 30 years there has been a commendable response to this challenge from the academic community[68,83–85]. Despite the scope of these and other efforts, however, to this day there remain large areas of ambiguity and disagreement, both with respect to definitions, and even more importantly, to the actual technologies and systems best suited for achieving sustainability[36]. No wonder that the US Congress, in the throes of trying to pass a hotly contested farm bill, would become frustrated with these definitional ambiguities and be forced to compromise over a number of key provisions[86].

Sustainable agriculture gets two definitions

When the farm bill process began in early 1990, proponents of reduced-input, organic-type technologies fell in line behind the definition of sustainable agriculture included in the bill as reported by the Senate Agriculture Committee, a definition that borrowed heavily from the 1989 NRC report, *Alternative Agriculture*[70]. According to the NRC Committee:

> Alternative agriculture is *not* a single system of farming practices. It includes a spectrum of farming systems, ranging from organic systems that attempt to use no purchased synthetic chemical inputs, to those involving the prudent use of pesticides or antibiotics to control specific pests or diseases. Alternative farming encompasses, but is not limited to, farming systems known as biological, low-input, organic, regenerative, or sustainable [p. 4].

Not surprisingly, USDA, commodity groups and agribusiness firms strongly opposed the Senate Agriculture Committee's definition of sustainable agriculture, which sounded eerily similar to the definition of organic farming developed by the 1980 USDA Study Team on Organic Farming [p. 9][9]. Conventional agricultural groups had managed to derail legislative support for organic farming in the early 1980s and were not pleased to see those ideas re-emerge, first in the guise of an NRC report on 'alternative' agriculture, and now once again as the centerpiece of sustainable agriculture in the 1990 Farm Bill. Using the word organic for certifying foods produced for the niche organic market—quite small in 1990—was an entirely different matter than allowing notions of organic agriculture to infiltrate and influence major farm bill provisions with the potential to affect the broader outlines of US agricultural policy and practice. Conventional agriculture would insist upon use of the definition of sustainable agriculture promoted by USDA: an agriculture that is 'environmentally, agronomically, and economically sound over long and short periods' [p. 304][86], but which did not embrace the notion of reducing the use of purchased inputs. Much of the farm bill debate would revolve around the differences between these two definitions.

Ultimately, the definition of sustainable agriculture—a mere paragraph of text in an enormously complicated, 700-page bill—'became one of the most significant and controversial issues of the 1990 Farm Bill. The definitional dispute fueled weeks of debate and, ultimately, a battle on the floor of the Senate that required every Senator to record his or her vote on which definition should become the law of the land' [p. 304][86]. On one side were those who argued that purchased, synthetic inputs could and should be reduced, and that doing so would benefit farmers, the environment and the general public. Opponents of this view contended that agricultural chemicals had been of enormous benefit to American production agriculture, and that the goal simply should be their more careful and efficient use. When agreement on a single definition for sustainable agriculture could not be reached, Congress would be forced to settle the matter by including both definitions in the bill's research title, authorizing research programs under each definition.

Organic agriculture in 1990: A look at its altered status

By 1990, organic agriculture in the US—as evidenced by the politics and provisions of the new farm bill—had reached a crossroads. One road was labeled 'certified organic,' an approach to farming and marketing that seemed to be gaining visibility, acceptance and support, especially from the consumer community. The goals of those taking this road were clear: most producers had accepted the definition of organic farming included in the OFPA, and were hoping for better and more predictable economic returns; organic foods processors, wholesalers, retailers and certifiers were on the cusp of creating a whole new industry, one modeled along the broad outlines of the conventional food industry that many on this road had come to reject. While no one on this road could have envisioned precisely where it would lead, or how difficult it would be to resolve the many disputes that lay ahead,

most travelers were filled with a sense of hope, excitement and accomplishment. At long last, organic agriculture had arrived: it had achieved governmental agenda status; it would now be certified; it was becoming an important, legitimate, national and international industry; its role and purpose in society had been resolved; it would soon be given a seal of approval from USDA, its staunchest critic just a few short years before. Travelers on this road now had sole, legal possession of the word organic. While some had accepted federal standards reluctantly—warning that a single set of formal national standards would accelerate the industrialization of organic agriculture, water down its agronomic principles and erode its basic philosophical tenets—overall the future looked clear and bright. For most of the travelers on this road, it was a heady, albeit somewhat unsettling, moment in the history of organic agriculture.

Meanwhile, travelers on the other road—now labeled 'sustainable'—comprised of those farmers, scientists, policy makers, new agenda groups, and other organic advocates who had come to embrace and support a less-pure form of organic agriculture, were left to ponder how this new, legally defined, market-focused organic program would affect the many traditional issues of concern more broadly throughout US agriculture: soil and water quality, soil erosion, wildlife habitat, social justice, farm worker safety, energy conservation, efforts to improve net farm income, and rural community development and family farms. These were the issues, after all, that had energized large segments of the expanding organic farming advocacy community throughout the 1980s. Now such advocacy would be conducted largely within the framework of sustainable agriculture, even though there seemed to be a great deal of confusion about what that word meant. Many of these travelers were quick to recognize, for example, that there were large-scale farmers —using heavy amounts of purchased inputs and monocultural cropping systems—traveling with them on this same road. Moreover, there were disquieting indications that promoters of agricultural chemicals and the newly emerging field of agricultural biotechnology would be traveling with them as well. They also noticed that this road was much wider and more crowded than the one labeled 'certified organic.' These proponents of organic-type technologies worried that their own beliefs would be overlooked amid these competitive, confusing and crowded conditions.

In fact, in a single decade, the politics of agriculture had greatly altered the definition, meaning and purposes of organic farming. The earlier idea that organic farming techniques might be incorporated into conventional systems, thereby reducing costs and helping to address various environmental concerns, was no longer widely discussed. Apart from their use on certified organic farms, organic technologies were now labeled sustainable and obliged to compete for recognition and support with an impressive and expanding collection of conventional agricultural technologies. Organic agriculture was now traveling exclusively on a road labeled certified organic. While this was, in many ways, an enormously positive and widely supported accomplishment, it did not greatly alter the overall agricultural political, environmental or structural landscape. Proponents and practitioners of organic farming—both certified and non certified—would still need to compete for scarce public resources (e.g., research, education, marketing and promotional support) with a myriad of emerging conventional technologies, all now claiming the mantle of sustainability, a powerful political symbol no longer reserved for use by organic, ecological and other low-input farming adherents. Proponents of conventional agriculture were now well positioned to continue propelling agriculture along the same energy-intensive, high-technology and high-cost structural trajectory it had been on since World War II, only now with the added advantage of being 'sustainable.' The consequences of these new institutional, definitional and political dynamics would soon become obvious to the supporters of organic agriculture, regardless of which road they had chosen—or had been forced to choose.

Organic Certification at the Federal Level: A Long and Bumpy Road

When the 1990 Farm Bill was signed into law and the OFPA became part of official USDA policy, few within the organic community could have imagined that it would be 12 difficult, exhausting years before this legislation would be implemented and shoppers would first notice the now familiar green and white label, 'USDA—Organic,' on organic products in an expanding array of retail outlets. (For the OFPA's formal provisions, see below.) Since the mid-1970s, when several nonprofit organic producer groups had established organic certification programs, participants in these efforts had known of the inherent complexities of defining certified organic farming in a way that would be acceptable to producers (and other elements in the organic supply chain) and be understandable and reassuring to consumers. Finalizing the federal rule under the OFPA simply elevated the matter of organic certification to another level of technical and political complexity. This brief retrospective is not the place to fully recount the history of this protracted and painful political process. Instead, we trace its broad outlines, including the sociopolitical and financial motivations of the major constituencies involved in these debates, as well as the impacts of a national program of organic certification upon broader notions of organic agriculture and its role in fostering agricultural sustainability.

Organic farming and marketing: The early years

As noted previously, the ideology of organic agriculture, even as late as the 1960s and most of the 1970s, had little to

do with certification and marketing of organically grown products. While organic farmers of this period did, in fact, sell some of their products as 'organically' grown, these transactions were mainly based upon relationships of personal knowledge and trust between farmers and consumers situated in what sociologists call dense local networks, not upon legally defined certification criteria. These early producer–consumer connections were the forerunners, at least in part, of what many now refer to as 'civic agriculture,' a term popularized by the late Tom Lyson a number of years ago[87]. Organic farmers of this era were motivated more by ideological factors—respect for nature, enhancing soil quality, improved health, environmental concern, community development, personal independence and the like—than by the desire for price premiums or other forms of financial gain. Well into the mid-1980s, many organic farmers continued to sell their products into conventional marketing channels, due largely to the lack of suitable and conveniently located organic wholesale and retail outlets, and a poorly developed certification and processing infrastructure. According to the results of *The New Farm* survey conducted by Rodale Press in 1979, in connection with USDA's organic farming report, '... only 20 percent of the organic and combination respondents received a premium price for organically grown products. Only 6 percent of the totally organic farmers reported receiving a premium price on all of their organic products' [p. 18][9].

Beginning in the early to mid-1970s—largely in response to increasing consumer demand for pesticide-free food, and the enhanced marketing potential represented by this trend—the number of organic grower associations expanded rapidly. The Maine Organic Farmers and Gardeners Association was organized in 1971 and claims to be the oldest such group in the US. Formed in 1973 as an information and support group for organic farmers, the California Certified Organic Farmers, one of the nation's first certification organizations, began to certify organic farms in the mid-1970s. In the Northwest, a group called Regional Tilth with chapters in Oregon, Washington, Idaho and Northern California, was formed in 1974 as a farmer support and information organization, but did not launch a formal certification program until 1982 when the Willamette Valley chapter of Oregon Tilth began to certify organic growers. By the early 1980s there were estimated to be some 35 such grower support and information groups active in 29 states [p. 18][9]. A handful of these largely grassroots, grower-based organizations either had certification programs in place or were beginning to consider developing them.

By the mid-1980s a number of private firms also were beginning to enter the field of organic certification. The entry of private, for-profit firms, coupled with the steady growth of not-for-profit, grower-based certification programs and the involvement of a handful of state-sponsored programs, had, by this time, begun to create numerous problems for the fledging organic marketplace. According to DiMatteo and Gershuny, by then 'there were multiple state laws and differing definitions of organic, conflicting standards among the handful of certifiers, and frustration among processors in finding consistent, reliable sources of organic products' [p. 254][88]. This *ad hoc* assortment of programs was ill designed to serve the certification and marketing needs of an industry that seemed poised for a period of relatively rapid growth. Indeed, organic agriculture had reached the point where it needed a more formal, recognizable, nationwide organizational structure acceptable to the disparate and increasingly contentious farmer and business interests within the overall organic community[88].

The Organic Foods Production Association of North America (OFPANA) was formed in 1985 to address these needs. (The group's name was changed to Organic Trade Association in 1994.) However, due to continuing distrust among certification organizations, farmer-based groups and various business interests, OFPANA's overall goal of creating a national certification program with increased reciprocity among individual certification programs would fail. The frustration associated with this unsuccessful, multi-year, private-sector effort to establish a national organic standards and accreditation program, coupled with the surge in demand for organic food following the 1989 Alar incident (highlighted on the CBS television program, '60 Minutes,' February 26, 1989), set in motion the prospect of turning to the federal government as the venue of last resort with the authority and resources to create and enforce a comprehensive national program of organic certification and accreditation.

Defining and Regulating 'Organic': Policy Making at the Federal Level

By the late 1980s, as we have seen, the organic agriculture movement was rapidly evolving into a national industry. Remarkably, within the span of a single decade, organic farming had largely shed its primitive, back-to-the-land image; had been featured in two major scientific reports[9,70]; was being studied (often under the rubric of sustainable agriculture) by a growing number of USDA and land-grant university scientists; had been the focus of numerous university and nonprofit on-farm research demonstrations and field days; had provided the grist for a great deal of congressional attention, including the launch of the LISA and SARE programs; had attracted the interest of many small- and mid-scale conventional farmers; and had begun to register impressive gains in the organic marketplace as consumers began to more aggressively seek out organic foods and other organic products. In all of this, there had been precious little time for the various stakeholders within the organic community to digest such rapid and significant changes. Many newer entrants into the field of organics (including

otherwise conventional food companies) welcomed the accelerating pace of change, and seemed eager to move ahead with the institutionalization (even the industrialization) of the industry. Some members of OFPANA (the so-called 'suits') earlier had reflected this impulse [p. 260][88]. Meanwhile, other members of the organic movement, especially those with deep philosophical attachments to the kinds of agrarian ideological precepts outlined earlier in this retrospective, had already begun to voice concerns about the future of organic agriculture within a more highly industrialized and regulated model.

Passage of the 1990 OFPA—and the rule-making process that followed in the wake of that historic legislation—would play out amid these politically contentious, polar-opposite organic world views. To a large extent these debates involved the meaning of organic, as though there is one singular, knowable organic essence. Yet, within the 30-year span encompassed in this narrative, much of the conflict has revolved around simple, predictable financial and political agendas. While many of these disputes existed long before passage of the OFPA, the establishment of federal organic certification standards drew considerable public attention to organic food and farming, raised the financial stakes for most participants in the organic industry, transferred control of the legal definition of organic to the federal government, and inadvertently created a larger and much more visible stage upon which to contest a range of key organic policy issues.

The organic farming movement in the US has long been, and remains, an incredibly diverse and dedicated entrepreneurial community of strong willed and often colorful individuals. The agricultural geography of the nation with its highly variable soils, ecosystems and micro-climates, and local and regional sociopolitical histories and traditions, reinforces the organic community's agronomic, ideological and political diversity. The inherent tensions within this complicated national constituency, represented by multiple sizes and types of farms, individual life experiences and philosophies, and personal and organizational agendas, were apparent when these stakeholders came together to fashion the OFPA, and later to make recommendations to USDA for the national organic rule.

In retrospect, given these complexities and the enormous risks and uncertainties associated with such a fundamental shift in how the rules of the organic industry would be established, administered and enforced, it is somewhat remarkable that this effort to create a federal organic certification scheme did not die aborning. Although most members of the organic community may have recognized and accepted (begrudgingly in many cases) the notion that structural changes were needed in order to eliminate fraud and to facilitate the industry's growth in interstate and international commerce, the system in place today owes much to those individuals who chose to see the rule-making process through to the end. Even now, some 20 years after passage of the authorizing legislation, and a decade after the program was fully implemented, participants continue to deal with a multitude of difficult issues and disparate philosophical points of view. The efforts of these pioneering policy makers, though by no means universally praised, form an important part of organic agriculture's history over the past 30 years. One can only speculate about what the organic foods marketplace might look like today in the absence of this pivotal page in the history of organic agriculture. It is easy to forget that the private sector had tried and failed to erect a national-level program of organic certification and accreditation.

Organic Foods Production Act: Formal provisions and some key issues

The OFPA of 1990, Title 21 of the 1990 Farm Bill[78], provided for establishment of the National Organic Program (NOP) to be housed in USDA's Agricultural Marketing Service. The Bill also provided for creation of the National Organic Standards Board (NOSB), composed of 15 industry representatives to be appointed by the Secretary of Agriculture and charged with 'development of standards for substances to be used in organic production,' the so-called National List. The NOSB was also authorized to 'provide recommendations to the Secretary regarding implementation' of the legislation. NOSB membership represents a cross-section of industry and consumer interests, including farmers, processors, retailers, environmentalists, consumers, the science community and one certifying agent. The OFPA required the development of national standards for organically grown agricultural products in order to assure consumers that products labeled organic, both raw and processed, would conform to the standards proscribed in the legislation and rules, and would have been certified as such by third-party certification agencies, accredited by USDA. The Act stipulates that the NOP is a marketing program, and that neither the Act nor its regulations are intended to address issues of food safety or nutrition. Producers and processors of organic products with less than US$5000 in sales per year are exempt from certification. The law provides for civil penalties against persons who knowingly sell or label products as organic that do not conform to NOP regulations[89].

When these deliberations began in the late 1980s—under the leadership of Senator Leahy and his key staffer (on the issue of organic agriculture), Kathleen Merrigan—most participants were hopeful, but also wary of where this process might lead[90]. Some questioned the entire enterprise. The notion of transferring formal control over the sensitive matter of organic production standards to the federal government, especially to USDA, which had long championed high-tech conventional production systems, seemed misguided if not totally unthinkable. While many taking this view may have recognized

the potential benefits of national standards, they simply could not support shifting control over the meaning of organic to an institution that had often ridiculed organic systems. For some, psychologically, this alone made the move to a USDA-controlled standard a 'tough pill' to swallow. Moreover, many feared that lodging authority for the meaning of organic within USDA would provide the so-called 'big boys' (those who often had little sympathy for the established characteristics and philosophical tenets of organic agriculture) with undue access to the reigns of conventional power, thus fostering a 'slippery slope' to weaker standards and the erosion of time-honored organic principles.

On the eve of the program's implementation, one such dissenter, Eliot Coleman, long-time organic farmer and advocate, expressed his opposition to federal standards with these words:

> Now that the food-buying public has become enthusiastic about organically grown foods, the food industry wants to take over. Toward that end the U.S. Department of Agriculture-controlled national definition of 'organic' is tailored to meet the marketing needs of organizations that have no connection to the agricultural integrity organic once represented. We now need to ask whether we want to be content with an 'organic' food option that places the marketing concerns of corporate America ahead of nutrition, flavor and social benefits to consumers ... The food giants that are taking over 'organic' want a simplistic list of ingredients so they can do organic-by-the-numbers. They are derisive about what they label 'belief systems,' and they are loath to acknowledge that more farmer commitment is involved in producing real food than any number of approved inputs can encompass [p. 1][91].

While Coleman's sharp-edged assessment almost certainly reflected a minority view within the organic community (after all, details of the NOP and the National List had been thoroughly debated and approved by the NOSB, a panel representing a cross-section of the organic industry), his perspective, nonetheless, illustrates the policy orientation and emotional intensity of a substantial segment of organic participants at that time. In his article entitled 'Beyond organic,' Coleman argued that the federal definition of organic, and the regulations promulgated to implement it, no longer represented the fundamental characteristics of organic agriculture. Thus, it would now be incumbent upon those who did understand and respect those principles to redefine organic, and thereby reclaim and perpetuate its true meaning and value. 'I encourage all small growers who believe in exceptional food and use local markets to use the word "authentic" to mean "beyond organic." With a definition that stresses local, seller-grown and fresh, there is little likelihood that large-scale marketers can appropriate this concept' [p. 3][91].

Later in 2001, the phrase 'beyond organic' would be popularized by Michael Pollan in a *New York Times* article in which he questioned the nature and direction of the so-called Big Organic (industrialized) version of the organic industry, while extolling the virtues of the more traditional, Little Organic (small-scale) version of organic farming[92]. Several years later, in his popular book, *The Omnivore's Dilemma*, Pollan further developed these themes, describing favorably, for example, the farming methods and philosophy of a well-known small-scale organic farmer from Virginia, Joel Salatin, while painting a somewhat less-than-flattering image of Whole Foods, as well as of Gene Kahn, who in 1990 had sold his company, Cascadian Farms, to Welch's (acquired later by General Mills where it would become Small Planet Foods), and as a result had become the 'poster child' for those organic pioneers who had chosen to embrace the industrialized version of organics over its more traditional forms[93].

Kahn had been among the 69 farmers interviewed in 1979 by members of the USDA organic farming Study Team. At that time, Kahn's farming and marketing operation fell squarely into the 'Little O' version of organic farming. Given Kahn's role within the organic farming movement of the 1970s and 1980s, many found it hard to accept his decision to become part of 'Big O' organics. Kahn defended his actions by arguing that the benefits of organic agriculture (e.g., reduced use of synthetic production materials, cleaner food and improved farm worker safety) were so important that no opportunity to extend its reach and impact should be overlooked, even if that meant allowing large corporations to enter the field.

Big O, Little O, and Beyond Organic: The evolving structure of organic agriculture

The accelerating growth in the sale of organic foods and other organic products[94] over the past two decades has been accompanied by equally dramatic shifts in the structure of organic farming and marketing, including the emergence of many new product labels. These changes appeal in varying degrees to the multiplicity of producer and consumer sectors that comprise the overall organic community. Clearly, for example, there is a great deal of consumer and producer support for the 'Little O' version of organic agriculture in the US. The dramatic rise in numbers of farmers' markets and various types of community supported agriculture (CSAs) over the past decade or so confirm the growing popularity of these largely traditional marketing structures, and the familiar farmer–consumer connections that they and other local marketing arrangements afford. Data collected by Adams and Salois[95] would seem to suggest a rising tide of consumer interest in simply buying more farm products directly from local producers, whether or not these local operations are certified organic. These researchers contend that this 'locavore' trend correlates strongly with passage of federal organic standards, and indicates a growing desire among consumers for a return to a time when organic was more closely associated with small

farms, community support and deeper notions of sustainability. Data reviewed in their study show that organic is no longer as strongly linked to these traditional notions as it once was, and for that reason many consumers have come to favor local over organic[95].

While the data and analysis presented by Adams and Salois[95] are persuasive, the fact remains that even a casual stroll through any Whole Foods Market (or any Walmart or Costco, for that matter) reveals a great deal of support for 'Big O' organics as well. Indeed, the meteoric rise of 'Big O' (industrialized) organic agriculture over the past 10–15 years, coupled with the simultaneous surge in the more traditional, smaller-scale forms of 'Little O' organic farming and localized marketing discussed by Adams and Salois[95], suggests an even larger point: the once mono-structural and ideologically homogeneous character of organic agriculture, including its practitioners, advocates, consumers and other adherents, has evolved into a highly pluralistic and complicated system of agronomy, marketing, economics, politics and consumption.

While more in-depth studies are needed to sort out the causes and implications of these alterations in the structure of organic agriculture (and consumer responses to them), this much seems relatively certain: many of these changes are the product of broad socioeconomic influences and would likely have occurred with or without the introduction of federal organic standards. Current tensions between and among advocates of 'Big O,' 'Little O,' and 'Beyond Organic' systems of farming and marketing may well be unavoidable at a time when the organic industry faces the challenges of establishing its role and configuration within the broader context of a rapidly changing society, especially one inclined to welcome (if not demand) ever greater and more specialized consumer product choices. While structural transformations of the kind occurring presently within organic agriculture will produce individual winners and losers, overall, as organic agriculture (regardless of its multiple forms) continues to attract support among consumers and the broader public, the collective good is likely to be substantial. As that process unfolds, the ideological and institutional diversity characteristic of today's organic agriculture (though painful for many organic participants) may prove to have been an essential element in the long-term growth of the overall organic industry.

Organic Agriculture Today: Recurring and Emerging Issues and Themes

As noted at the outset of this retrospective, over the past 30 years organic agriculture has undergone enormous innovation and growth in the US and throughout the world. During this period, the science, politics, symbolism and institutional underpinnings of organic agriculture in the US have been largely transformed. Today, for example, unlike three decades ago:

- many conventional scientists now conduct research on organic agriculture, acknowledging and even promoting the ecological and environmental benefits of organic systems[38,96];
- other members of the academy have described and extolled the social and economic characteristics and advantages of small farms and localized marketing systems, often giving special attention to organic operations[87,97];
- the federal government now provides the institutional framework for administration and enforcement of national standards for certified organic foods production, manufacturing and marketing;
- many large conventional food manufacturers, distributors and retailers now proudly display and promote a wide variety of certified organic products;
- farmers' markets, CSAs and other localized marketing arrangements have grown in number and popularity, and together with organizations such as Chef's Collaborative and a number of high-end restaurants have helped create and sustain a vibrant, dedicated and growing locavore movement; and
- a number of foundations have provided financial support for both organic and sustainable nonprofit organizations.

While these institutional alterations all help to fortify and enhance organic agriculture's political and scientific credibility, a number of closely related developments bear even more directly upon the industry's overall capacity to mobilize, focus, and deliver political messages and public policy proposals. To wit:

- consumers have responded enthusiastically to the organic foods marketplace, producing double-digit sales growth for organic foods and other products over the past 10–15 years[94], and in the process have made an important political statement to policy makers;
- organic producer associations, certification organizations, specialized organic retailers, and organically oriented nonprofit organizations have grown steadily in size, number and influence;
- many environmental, consumer, farmland preservation and rural development groups now include organic farming policy work in their respective portfolios, thus broadening the political base of support for organic agriculture;
- the interests and perspectives of organic and sustainable agriculture are now skillfully represented in national policy debates by various industry and nonprofit groups and coalitions;
- books, popular articles and peer-reviewed journals provide a continuous flow of credible information and commentary on organic agriculture to both scientific and lay audiences; and
- sympathetic press accounts dealing with the benefits of organic and sustainable farming operations appear

frequently in both local and national media outlets, often with catchy titles, enticing story lines and suggestions for how consumers can support farmers practicing various alternative production and marketing methods and strategies. (A recent article in *The Denver Post*, for instance, entitled 'How now, sustainable cow?,' typifies this popular genre[98].)

As these selected developments illustrate, organic agriculture in the US today is far different than it was during the 1960s and 1970s[1]. Throughout this early period, the core elements of the organic farming movement consisted, essentially, of a fledgling but intrepid grassroots contingent of pioneering farmers; a modest number of small, mostly rural, largely voluntary nonprofit organizations; a handful of supportive writers, publishers, retailers and academics; and a small, but slowly expanding, community of interested consumers. With the exception of research conducted at the Center for the Biology of Natural Systems at Washington University in St. Louis, a non-land-grant institution[99,100], and the University of Nebraska[101], formal research programs on organic farming were nonexistent prior to the early 1980s.

Much of organic agriculture's growth over the past 30 years (as noted previously) has related to mounting scientific and societal concerns associated with conventional agriculture, particularly its heavy dependence on nonrenewable, and increasingly expensive, petroleum-based resources, and the potentially adverse impacts of many conventional technologies on the natural resource base, human and animal health, rural communities and the structure of American agriculture. These and other factors, including growing concerns about food quality and safety, caused many scientists, policy makers and ordinary citizens to begin reassessing the benefits and costs of conventional agricultural production systems, and to begin exploring how organic farming methods might, at least to some extent, be incorporated into conventional systems. These concerns and reassessments, combined with the determination and skill of organic farmers and their supporters, slowly allowed organic agriculture to play an increasingly influential role in the contentious, protracted and divisive debates of the past three decades over how to achieve a more sustainable agriculture in the US, and around the world.

Today, despite these impressive achievements, efforts to expand organic agriculture's footprint in the US must address a number of recurring and emerging issues. While there seems little doubt that organic agriculture will continue to occupy a prominent place on governmental, societal and personal agendas, its future character and direction are by no means certain. It is possible that the issues and battles that lie ahead may prove to be even more daunting for advocates of organic agriculture than those encountered over the past three decades. What are these issues, and how will they influence the future of organic agriculture?

Sustainable agriculture

The word sustainable did not appear prominently in early debates regarding the costs and benefits of either organic or conventional agriculture. Instead of claiming that organic farming deserved governmental support because it was sustainable, the 1980 USDA *Report and Recommendations on Organic Farming* simply characterized organic systems as having the potential to help conserve 'soil resources and the environment' [p. v], or possibly to address 'energy shortages, food safety, and environmental concerns' [p. iii][9]. In summarizing the basic tenets of organic agriculture, the Report concluded that '... organic farmers seek to establish ecologically harmonious, resource-efficient, and nutritionally sound agricultural methods' [p. 9]. In the period surrounding its publication, the notion of sustainability had not yet become agriculture's dominant verbal endgame, and the word sustainable had not yet emerged—as it soon would—as one of the most coveted, ubiquitous, symbolically powerful and politically charged words in the agricultural lexicon.

It was not until the word organic became the target of elevated and sustained attacks from the conventional agricultural community that organic proponents began to substitute other terms (including sustainable) in place of the word organic, to make organic farming more palatable to the agricultural scientific and policy-making communities. During this linguistic transition, it is important to remember that it was the terminology that changed, not the technology. Throughout much of the 1980s, as the labeling of organic technologies shifted toward the word sustainable, advocates of organic farming and those members of the science community sympathetic to organic approaches seemed relatively comfortable using these words more or less interchangeably. By the end of the 1980s, however, the science community, facing mounting peer pressure and continuing USDA and industry criticism of organic methods, had gravitated almost exclusively to use of the word sustainable. Meanwhile, the organic community began to focus its attention more heavily on organic certification and other aspects of the organic foods marketplace, with sustainability becoming only one of several reasons why consumers chose to support organic farming. Thus, throughout much of the 1980s, but especially during the first half of that decade, use of the words sustainable and organic, two of agriculture's most symbolically powerful terms, were viewed as somewhat synonymous by members of the organic community and those agricultural scientists and policy makers most concerned about the negative externalities of conventional agriculture.

These developments did not go unnoticed within conventional agricultural circles. Once the organic farming community—and a distinct minority of scientists and policy makers—began to suggest that organic technologies were sustainable, and that conventional technologies

were not sustainable, proponents of conventional approaches vigorously entered the sustainability debate. The specter of organic technologies emerging as one of agriculture's best hopes for achieving sustainability represented an even larger threat to conventional agricultural interests than did the expanding organic foods marketplace, which remained quite small prior to passage of the OFPA in 1990.

By the late 1980s, the conventional community had begun to marshal its considerable resources in defense of chemical production inputs, precision agriculture, reduced tillage, biotechnology, large specialized farms including CAFOs, and other conventional methods. Proponents insisted that these technologies were now more necessary than ever in the quest for sustainability, which, under the conventional definition, emphasized the challenge of feeding a rapidly expanding world population. The launch of USDA's LISA program in 1988 added to these tensions. The idea of linking sustainability with low inputs was repugnant to conventional agriculture. The phrase, 'Low inputs mean low outputs,' became a common refrain as conventional agriculture sought to associate its high-input technology with sustainability. This issue, as noted earlier, came to a head in the 1990 Farm Bill debates. Efforts by the conventional agricultural community to discredit organic and other low-input approaches, and to emphasize the importance of 'efficient and prudent' use of farm chemicals, biotechnology and other conventional practices in achieving a sustainable agriculture, has been a central theme in agricultural policy debates for most of the past three decades.

Meanwhile, the organic community has sought to expand the meaning of sustainability to include not only environmental, ecological and nutritional benefits, but also issues such as social justice, farm worker safety and security, animal welfare and a more balanced farm structure, emphasizing the role of small farms and healthy rural communities. Much of the impetus to move 'beyond organic' revolves around these kinds of issues, and may be seen in the growth of new certification programs and product labels[102]. For example, a five-step animal welfare rating system for meat and other livestock products, announced in 2010 by Whole Foods Market and developed in coordination with the nonprofit Global Animal Partnership, would allow consumers to better understand where and how farm animals are raised. The highest rating would go to those producers whose animals spend their entire lives on the same farm[103].

The NRC recently characterized agricultural sustainability as 'a complex, dynamic, and political concept that is inherently subjective in that different groups in society place different emphasis ...' [p. 5] on the various goals typically used to help define it[36]. According to the NRC, these goals include:

- Satisfy human food, feed and fiber needs, and contribute to biofuel needs.
- Enhance environmental quality and the resource base.
- Sustain the economic viability of agriculture.
- Enhance the quality of life for farmers, farm workers and society as a whole [p. 4].

Unfortunately, broad, goal-type statements such as these invite multiple arguments in defense of almost any combination of agricultural production methods, leaving the critically important concept of sustainability at the mercy of competing political, ideological and market forces. Thus, from a purely political perspective, organic agriculture (along with other low-chemical approaches) has lost its early, and nearly exclusive, claim on sustainability, a word that may at some point—if it does not already—hold even greater symbolic appeal to the broader agricultural community, and perhaps even to society in general, than the word organic.

The importance attached to sustainability by the conventional agricultural community may be seen in its determination to include conventional production technologies in various efforts to develop a certified label for sustainable agriculture. In late 2010, for example, the conventional agricultural groups involved in a 2-year-old process to develop a national standard for sustainable agriculture, convened by The Leonardo Academy, resigned from the Committee. In explaining the resignations, the American Soybean Association (ASA) cited 'serious systemic limitations and chronic biases that are inherent in the structure that The Leonardo Academy has set up for this initiative'[104]. The ASA further alleged that ... 'the Committee is dominated by environmental groups, certification consultants, agroecology and organic farming proponents. These groups have neither the vision nor desire to speak for the farmers of mainstream agriculture who produce more than 95 percent of the food consumed in or exported by the United States.' The Association further noted that it '... supports developing a progressive definition of agriculture sustainability that encompasses profitable, intensive production and encourages consumer acceptance of biotechnology enhanced products and satisfies food, feed, fiber and biofuel needs'[104]. Should conventional agricultural interests be successful in shaping and promoting into the marketplace a sustainable label (54 commodity and other conventional farm groups also withdrew from the Academy process[104]), it would represent an enormously important public relations achievement, enhance the image of conventionally produced foods (that would be labeled sustainably produced), reassure conventional farmers, confuse policy makers and consumers, and pose an important barrier to the expansion of organic foods and farming.

As the organic community moves 'beyond organic' by broadening the definition of sustainability, similar claims by conventional agriculture can be expected to increase. Evidence of this emerging trend may be seen in the promotional literature and outreach of the relatively new Association for the Future of Agriculture in Nebraska

(A-FAN). This nonprofit organization was formed by a number of conventional agricultural groups in the state: Nebraska Cattlemen, Nebraska Corn Growers Association, Nebraska Farm Bureau, Nebraska Pork Producers Association, Nebraska Poultry Industries, and Nebraska Soybean Association. Its website stresses that A-FAN's purpose is 'to assist farmers seeking to make responsible changes to their farms to remain economically viable and environmentally and socially responsible, and to share with Nebraskans a truthful representation of farm life and the connection between it and Nebraska's economic and social well-being'[105]. A-FAN spokespersons, unveiling the group on RFD-TV, stressed repeatedly the commitment of its farmer members to animal safety and welfare, as well as to other commonly used indicators of agricultural sustainability[106].

As long as the technologies and systems needed to foster a sustainable agriculture are debated and contested, American consumers will be left to sort out what is likely to be an ever more complicated marketplace of symbols, labels and certification programs, as well as competing claims regarding the sustainability of various products and technologies. Meanwhile, agricultural policy makers will face an equally confusing set of choices when considering how to apportion increasingly scarce dollars for agricultural research, education and other forms of support.

Public agricultural research

Support for organic systems research. For the past three decades, the issue of public funding for research and education programs directly relevant to organic farming systems has been one of the most important recurring themes in the debates surrounding the character and potential of organic agricultural methods. Organic adherents have argued that conventional, disciplinary research programs fail to address the inherent ecological complexities and the physical, biological and chemical interactions occurring within organic systems. Organic farmers and their supporters have called for holistic, interdisciplinary, systems-oriented research programs designed to identify, measure and better understand these complexities. During the period covered in this retrospective, the USDA Study Team on Organic Farming was among the first to emphasize the need for such an approach, calling for programs designed to '[i]nvestigate organic farming systems using a holistic approach' [p. 88][9]. The Study Team then explained why such programs were needed:

> The USDA case studies revealed that many organic farmers have developed unique and productive systems of farming which emphasize organic recycling and the avoidance or restricted use of chemical fertilizers and pesticides. It is also likely that these systems are highly complex and involve unknown or poorly understood chemical and microbiological interactions. Much of the research conducted to date that relates to organic farming has been somewhat piecemeal and fragmentary. A holistic research approach, which may involve the development of new methodologies, is needed to thoroughly investigate these interactions and their relationship to organic waste recycling, nutrient availability, crop protection, energy conservation, and environmental quality [p. 88].

Many of the Study Team's other recommendations, in varying degrees, reflected the need for new research approaches, including interdisciplinary efforts [pp. 86–94].

Nearly a decade later, the NRC, while reviewing the role of alternative farming methods in modern production agriculture (understood at the time to include organic methods), also appealed for expanded programs of interdisciplinary research. According to the NRC Committee, '... agricultural research at the land-grant universities and the USDA has been extensive and very productive' [p. 137][70]. However, the Committee continued:

> Most of the new knowledge has been generated through an intradisciplinary approach to research. Scientists in individual disciplines have focused their expertise on one aspect of a particular disease, pest, or other agronomic facet of a particular crop. Solving on-farm problems, however, requires more than an intradisciplinary approach. Broadly trained individuals or interdisciplinary teams must implement the knowledge gained from those individual disciplines with the objective of providing solutions to problems at the whole-farm level. This interdisciplinary problem-solving team approach is essential to understanding alternative farming practices ... [M]ost research has focused on individual farming practices in isolation and not on the development of agricultural *systems* [pp. 137–138].

More than two decades after this NRC appeal for expanded programs of interdisciplinary research on alternative farming systems (and over 30 years since the USDA Study Team on Organic Farming had reached a similar conclusion), many agricultural scientists, especially those who have actually studied organic farming, continue to argue that the unique features of organic systems require interdisciplinary approaches. According to Drinkwater, for example, conventional farming systems are based on a 'command and control' philosophy that 'has led to the development of practices and inputs aimed at simplifying and reducing variation in agricultural systems ... In contrast, the use of systems thinking and integrated management strategies is fundamental to organic agriculture ... [O]rganic production systems are intentionally multifunctional' [p. 21][107]. As the science of organic agriculture has expanded over the past 30 years, these and other calls for more interdisciplinary research have acquired a heightened level of credibility and urgency, and, in recent years, would seem to have had a positive impact on organic research funding levels.

As late as 1997, however, investigators could find little evidence of progress. In a careful review of USDA's

Current Research Information System (CRIS) conducted in the mid-1990s, Mark Lipson, policy analyst at the Organic Farming Research Foundation, found that a mere 34 research projects out of some 30,000 could be classified as focusing directly on organic systems, within 'an experimental setting consistent with conditions found on working organic farms' [p. 7][108]. Lipson further concluded that these 34 projects represented 'less than one-tenth of one percent of USDA's research portfolio, both numerically and fiscally' [p. 7]. Some 267 additional projects were deemed to be 'compatible with organic methods, but not explicitly placed in a context of organic agriculture' [p. 7].

Faced with these persistently low levels of research support in the years following implementation of the OFPA in 2002 (which provided a legal definition of organically produced food), proponents of organic systems added the principle of 'fair share' to their ongoing funding strategies. Armed with statistical information regarding the amount of organic food sales—approximately 3.5% of the value of total food sales as of 2010[109]—organic advocates settled on the notion of equivalency, meaning that a fair share of research dollars devoted to organic research would be equivalent to the organic percentage of total food sales. The total appropriation in Fiscal Year 2010 for federal- and state-level public agricultural research, education, and extension was nearly US$2.9 billion[110]. Thus, the equivalency or fair-share standard suggests that organic research funding annually should be approaching US$100 million. In fact, organic research funding in 2010 was slightly less than half this amount. However, according to Kathleen Merrigan, Deputy Secretary of Agriculture, 'Another $41 million of ARS research is compatible with organic farming systems, but is not directed towards specific organic research objectives' [p. 11][111].

Political and institutional barriers. Clearly, these recent estimates represent a substantial improvement in the level of funding for organic research and other forms of technical assistance for farmers wishing to transition to organic practices. It should be noted, however, that a substantial majority of these gains came recently, with passage of the 2008 Farm Bill[112]. Thus, some 30 years after organic agriculture moved onto the public agricultural agenda in the US[9], it is important to ask why it has taken so long to achieve these minimal levels of funding when compared with conventional agriculture. Here we note briefly some of the more intractable political and institutional forces arrayed against proponents of organic agricultural research. As Hadwiger[113] demonstrated 30 years ago, the politics of agricultural research is complicated.

In the 2010 NRC report dealing with sustainable agriculture, the authors noted that agricultural research remains 'largely organized by discipline ...' and then offered the following explanation for the 'slow movement of public scientists toward more holistic and agroecological approaches to agricultural science and technology ...' [p. 322][36]. According to the Committee:

> Aside from the influence of formal research program funding priorities, long-term cultural and cognitive routines of agricultural scientists generate assumptions about the current and future importance of different kinds of agricultural systems and influence their views of the viability of alternative approaches to scientific research[114]. Moreover, institutional and disciplinary reward mechanisms, publication opportunities, and increasingly specialized skill sets mitigate against the likelihood that young agricultural scientists will be successful pursuing careers using interdisciplinary, holistic, or alternative technological approaches[115,116] [p. 322].

Focusing initially on the Committee's third and final point in the above passage, it would appear that 30 years after publication of USDA's *Report and Recommendations on Organic Farming*, and despite the efforts, over this period, of organic and sustainable agriculture supporters to influence the research priorities of the USDA/land-grant university system, these institutions have yet to fully address the training, financial and professional incentives, and the psychic rewards, offered to both seasoned and aspiring agricultural scientists wishing to pursue interdisciplinary research.

In addition to the organizational disincentives for interdisciplinary research noted by the NRC Committee, it is equally important to focus on the Committee's opening phrase in the above quotation: 'Aside from the influence of formal research program funding priorities ...' [p. 322][36]. Here, the Committee seems to be acknowledging that the politics of establishing research priorities may also hinder the development of more interdisciplinary research. Indeed, there has long been substantial agreement among policy analysts that politically powerful agricultural commodity, trade and industry groups have consistently held sway in setting the overall priorities and direction of agricultural research policy[117]. These entrenched and politically experienced research policy subsystems consist generally of specialized commodity producer associations (and their industry counterparts), sympathetic House and Senate appropriators who may be aligned politically with such groups in their respective states and districts, and a supportive agricultural research bureaucracy organized largely by disciplinary categories corresponding to the needs and expectations of commodity, trade and industry clientele groups. The influence of these kinds of so-called political 'iron triangles' (sometimes referred to as sub-governments) has been well documented by policy researchers, and is not limited to the politics of agricultural research [pp. 71–74][117].

Most agricultural policy analyses, however, particularly those conducted prior to the ascending influence of the new agricultural agenda groups discussed earlier, have generally concluded that the American agricultural establishment 'has comprised one of the most closely knit, impenetrable cadres of political decision makers in the

whole of American government'[118]. Thus, while it would be difficult for any new claimant for limited agricultural research dollars to compete effectively against these specialized, commodity-based research policy subsystems—that often compete vigorously against one another for limited funds—it may be especially challenging for proponents of organic agriculture to alter the priorities of these established, often symbiotic, sub-governments. Not only does organic agriculture represent one more competitor for limited funds in an already highly competitive overall agricultural research system, the interdisciplinary, ecologically based nature of many of its funding requests also represents an organizational challenge to the manner in which that research would need to be planned, conducted and evaluated, thus disrupting established bureaucratic missions and routines.

The recent uptick in both authorized and mandatory funding for organic agriculture research and other support programs, as represented in the 2008 Farm Bill (see Lipson et al.[112]), would seem to indicate some degree of realignment within the agricultural research sub-government. Indeed, it may now be more accurate to think of the agricultural research sub-government as a 'policy community' that, according to Anderson, '... is broader and more open in participation than an iron triangle ...' [p. 73][117]. A more complete description of the agricultural research system as it has evolved over the past 30 years, and is presently configured, must await a thorough empirical analysis.

Finally, the NRC Committee drew attention to the notion that 'long-term cultural and cognitive routines of agricultural scientists generate assumptions about the current and future importance of different kinds of agricultural systems and influence their views of the viability of alternative approaches to scientific research' [p. 322][36]. Presumably, in other words, scientists make personal judgments about the importance of larger societal and agricultural trends and needs, and the probable impact of those trends on the likelihood of financial and other forms of professional support—and personal rewards—likely to accompany their involvement in a variety of basic and applied research programs. Thus, the growing interest in organic farming among members of the conventional agricultural research community may well be tempered by both the symbolism and ideology of the high-yield, high-technology agricultural production systems that continue to dominate the world of agricultural science, and agriculture in general.

Today, for example, major agricultural media outlets, agricultural research institutions, private firms involved in the development and sale of conventional production input technologies, and major commodity organizations have all begun to stress the challenges facing American agriculture of feeding a worldwide population of 9 billion people by the year 2050, while at the same time being better stewards of the environment, honoring the family farm and its agrarian traditions, and improving animal welfare. These stated challenges, in various iterations now appearing widely on conventional agricultural websites and in other media outlets, have been formalized under the name 'Farmers Feeding the World'[119]. This campaign, unveiled in 2010 by Farm Journal Media, is an initiative of the newly formed nonprofit Farm Journal Foundation. Billed as an industry-wide, agricultural anti-hunger campaign, its goals have been embraced by Senator Richard Lugar, former chairman of the Senate Agriculture Committee. In a video clip endorsing Farmers Feeding the World, Lugar said:

> Farmers everywhere are facing a big challenge: They will need to produce enough food to feed a population that is projected to grow to 9 billion by 2050. Their ability to do so will come largely from proper stewardship of scarce natural resources, like land and water, as well as making the best use of technology-based sustainable production practices. To meet that challenge, Farmers Feeding the World is rallying the United States agriculture industry to assist organizations on the front lines of the fight against hunger, while educating the general public about modern agriculture as an essential component of the solution. Farmers Feeding the World will highlight the history of tenacity, hard work, discovery and know-how that make American farmers uniquely qualified to help 925 million people suffering from food insecurity[120].

This campaign, whose goals are highly laudable and whose membership includes nearly all major conventional agricultural producer and industry groups, illustrates conventional agriculture's ability to shape the flow of information to the food and agricultural community, and even to some extent, to the larger society. It also demonstrates the determination of mainstream agriculture to control the agricultural policy agenda, including research, trade and development. It would be nearly impossible, given the origin, character and magnitude of this campaign, for most agricultural scientists to resist, or even question, its compelling and symbolically powerful goals and messages. In addition to extolling the benefits of modern, high-yield agricultural technology in support of efforts by US farmers to 'feed the world,' the campaign includes an appeal for individual and corporate financial donations to assist groups such as Heifer International in delivering food aid and helping farmers in the developing world become more self-sufficient in food production. According to the Foundation's website, US$20 million annually would be sought for these purposes[121].

This humanitarian element of the overall campaign, no doubt sincere and certainly commendable, serves to reinforce the larger message of Farmers Feeding the World: namely, that feeding 9 billion people by 2050 can be achieved only through the continued development and adoption of modern farming techniques by US farmers and their counterparts in other developed countries. Visitors to the Farmers Feeding the World website are reminded, for example, in an animated video clip, that: 'Yesterday's agriculture cannot feed 9 billion people.' Organic and other low-chemical farming methods are

conspicuously absent from the campaign's discussion of production technologies with the capacity to help address the global hunger challenge. The origin, tone, and powerful imagery of the Farmers Feeding the World campaign, coupled with its pervasive reach within agricultural institutions, including the research community, reminds us again to consider the second point of the NRC Committee's summary statement regarding reasons for the continuing disciplinary organization of agricultural research: '... [C]ultural and cognitive routines of agricultural scientists generate assumptions about the current and future importance of different kinds of agricultural systems and influence their views of the viability of alternative approaches to scientific research' [p. 322][36].

Despite the barriers to organic farming research posed by these and other ideological and political characteristics of our conventional agricultural institutions, over the past two decades or so many agricultural scientists have forged successful, even prominent, careers while focusing much of their research and teaching efforts on organic systems and publishing the results of their research in new peer-reviewed, interdisciplinary journals. Considering that the agricultural sciences, as we have seen, remain organized largely along disciplinary lines, including the publication of prominent disciplinary journals, the fact that a growing number of mainstream agricultural scientists would choose to place their work in these relatively new interdisciplinary journals demonstrates at least two important points: (1) disciplinary journals have tended to overlook the importance of interdisciplinary work, especially work focused on organic-type production systems; and (2) increasing numbers of agricultural scientists are gravitating toward the scientific challenges associated with exploration of ecologically based, organic-type farming systems. As these events have unfolded, more such work has appeared in traditional publication outlets, including some of the world's most prestigious journals (e.g., see Reganold et al.[23,122,123]).

These efforts have made important contributions to the science community's understanding and acceptance of organic farming systems, identified key knowledge gaps, elevated the scientific image of organic farming, and helped to legitimize the need for expanded, interdisciplinary research on organic farming as perceived by both political and scientific audiences. Proponents of organic agriculture are mindful of the increasing attention and respect shown to organic farming by some members of the conventional research and policy communities. Nonetheless, most continue to believe that current efforts fall far short of those needed to allow organic agricultural systems to reach their full potential, and for the ecological and environmental benefits associated with these systems to be more fully understood and more widely incorporated into farming systems both here and abroad.

Organic adherents, including a growing number of agricultural scientists and policy analysts, believe that the ecological, agronomic and production characteristics of organic systems can and must play a larger role in the goal of feeding the world's population[124]. Unlike the Farmers Feeding the World campaign that, despite its humanitarian component, emphasizes the high technology and high yields associated with a US export-oriented strategy, proponents of organic farming argue that global efforts to reduce poverty and hunger should focus more attention on development of low-cost, organic-type technologies appropriate for small farms and localized marketing systems[125,126]. Moreover, it is important to note that the bulk of US grain exports go to the most highly developed countries, not to the poorest and least developed ones[127].

For these and other reasons, organic ideology favors a multi-faceted strategy for food production, one that rests more heavily upon the diverse human and natural ecology of local soils, crops, climates, communities and cultures that exist throughout the world. Advocates argue that this approach would go a long way toward making it possible for more farmers everywhere to feed themselves and their communities. This strategy would, of course, require a prolonged and substantially greater investment in holistic, interdisciplinary and systems-oriented research conducted by teams of investigators representing the full range of agronomic, ecological, economic and policy sciences. As the foregoing discussion illustrates, however, given the politics of agricultural research, securing expanded levels of support for ecologically oriented interdisciplinary approaches represents a very tall order, indeed.

Public agricultural policy and farm structure

For the past several decades, organic farming advocacy has been conducted against the backdrop of a larger debate over how American agriculture should be structured. Successful organic farming operations have long been associated with small- to mid-sized, family-type, mixed crop–livestock farms, particularly for farms located in the Midwest agricultural heartland. The intensive management required of organic farming operations largely accounts for the belief that smaller farms generally may be more compatible with organic systems. In sharp contrast to this farm enterprise model, however, trends in US farm structure—farm size expansion, specialization, intensification, and mechanization—especially since World War II, have combined to create a relatively 'non-organic' overall farm structure, one consisting of ever-larger, more specialized farms, reliance upon heavy and widespread use of synthetic fertilizers and pesticides, monocultural cropping systems, and separation of crops and animals[128]. One result of these trends has been the gradual decline in numbers of family, or mid-sized farms (numbers of small farms have increased during this period), in what many have called the 'disappearing middle' within the overall structure of US agriculture. These technological, economic, political and social forces

continue to drive American agriculture in the direction of an increasingly 'non-organic' farm structure.

These structural issues must be addressed at a time when some organic proponents have begun emphasizing the survival of mid-sized farms as both a technological necessity and an ethical imperative, not only for the future of organic-type systems, but for the future of the planet as well. Fred Kirschenmann, for example, argues that the industrial character of US farm structure, relying so heavily upon relatively inexpensive, nonrenewable resources, has overlooked the importance of social and human capital, resulting in ... 'a disastrous effect on the nation's "independent family farmers"' ... the kind of farmers needed to ... 'meet the challenge of sustaining a food system that can provide adequate amounts of food for an increasing human population in the face of peak global oil production, degraded soils, depleted fresh water supplies, and more unstable climates' [p. 331][129]. The plea for preserving a solid core of mid-sized farms is not, he writes, a 'matter of "saving the family farm"' [p. 331]. Rather, it is because these are the kinds of farmers who possess the ... 'ecological and cultural wisdom and commitment required to restore the physical and biological health of our soils. They are the farmers who owned their land, lived on their land, were intimately related to their land, and planned to pass it on to future family members—all factors that nurtured a culture of caring for the land' [p. 330]. Despite the urgency attached to reversing (or at least stabilizing) the loss of mid-sized farms, by Kirschenmann and other proponents of organic farming, success in altering this and other interrelated trends in US farm structure is far from certain.

While many organic food consumers and other supporters of organic agriculture, including growing numbers of scientists and analysts, may view organic systems as a way to foster a more decentralized, less industrialized and more sustainable farm structure, others see the matter quite differently. A recent article in *Foreign Policy* magazine entitled 'Attention Whole Foods shoppers,' by Robert Paarlberg, a well-known analyst of food and agriculture policy at Wellesley College, undoubtedly reflects the views of many within the conventional agricultural community. According to Paarlberg, 'If we are going to get serious about solving global hunger, we need to de-romanticize our view of preindustrial food and farming. And that means learning to appreciate the modern, science-intensive, and highly capitalized agricultural system we've developed in the West. Without it, our food would be more expensive and less safe'[130].

Paarlberg is not alone. For most of conventional agriculture, the relatively 'non-organic' farm structure now in place throughout US agriculture represents a positive, even stunning, technological and policy achievement. Meanwhile, many supporters of the industrial model continue to view organic agriculture, as Paarlberg phrased it, as 'preindustrial food and farming'[130]. The many substantial efforts over the past three decades to enhance the scientific understanding and image of organic production systems has failed to convince most conventional agriculturists, many of whom continue to regard organic farming in much the same way it was viewed (and dismissed) decades ago. The following passage captures this sentiment:

> ... [O]rganic food has garnered an extraordinary amount of attention from the media and, along with 'local' food, is a darling of foodies and environmentalists, who talk up its civic virtues and benefits to the environment. There's just one problem with this: agriculture has moved away from small-scale, local, and organic farming because these types of farms are land and labor-intensive and don't do a very good job of feeding lots of people. In addition, they are *not* definitively better for the environment, and their growth would lead to higher food prices than most Americans are willing to pay [p. 1][131].

The views of Paarlberg[130] and Haddad[131] illustrate a critically important point: The controversy that has raged around organic versus conventional agriculture for the past several decades transcends arguments about the benefits and costs of various technologies and farming systems *per se*; much of the debate revolves around the issue of farm structure itself. In fact, the structure of American agriculture produces winners and losers. The growing scale and specialization of US farm structure favors a wide array of chemical and farm machinery companies. The ability to capitalize farm program benefits into the value of farmland provides an economic advantage to large landholders. Monocultural cropping systems benefit those companies that manufacture and sell synthetic fertilizers and pesticides. Vertically integrated CAFOs benefit large-scale feeders, meat packers and poultry processors. A more 'organic' farm structure, on the other hand, one characterized by widespread use of legume-based crop rotations, integration of crops and animals, smaller and more decentralized processing and marketing facilities, smaller-scale machinery and larger numbers of small and mid-sized farms, would greatly alter the mix of winners and losers in US agriculture. The stakes are high for the beneficiaries of the current relatively 'non-organic' farm structure, and they can be expected to fight hard to keep in place those policies that have helped shape it.

US farm structure has evolved along with various socioeconomic and political issues, including but not limited to: agricultural commodity, tax, credit, and research and education policies. Relatively low energy prices (at least until recently), rapidly rising land prices and the competitive nature of farming have often exacerbated a cost-price squeeze for producers, adding to the pressures (and opportunities) to expand the size of their operations and improve margins through enterprise specialization, intensification and mechanization[128]. The broad outlines of these institutional and policy dynamics may be seen in the following highly abbreviated sketch.

Inflationary land markets have encouraged farmers (especially those well-capitalized with access to credit) to expand their operations through purchase of additional land. Attractive interest-deduction policies have also supported farm-size expansion. Mechanization, which has accompanied the trend toward larger farms, has been encouraged by investment tax credits and accelerated depreciation schedules. Enhanced mechanization has helped to reduce labor costs, while farm-size expansion has allowed the costs for fixed investments to be spread across more acres or other specialized production enterprises. The switch to more specialized monocultural cropping systems and the elimination of crop–animal forage systems, on most farms, is largely responsible for the intensified use of synthetic fertilizers and pesticides. Monocultural cropping systems such as corn, soybeans and wheat require use of these purchased inputs to provide crop nutrients and control pests. Taken together, these alterations in farm structure and management have helped to free farmers from the confining aspects of mixed crop–livestock operations, making current trends attractive to many farmers. As one Midwest wag put it several years ago: 'Farmers around here work really, really hard—two months in the spring and two months in the fall.' This comment by a large-scale producer in Illinois serves to reinforce the notion that current US farm structure enjoys widespread support among many, if not most, large-scale farmers, and from the input supply industry that supports them.

Agricultural commodity policy has also tended to favor larger farms specializing in monocultural cropping systems[132]. Although commodity policy is incredibly complicated and has undergone numerous changes since the 'modern' era of farm policy was first advanced during the New Deal, two recurring features of commodity policy, crop bases and crop yields, have endured (with some modifications) and often have influenced farmer decision-making regarding what crops to grow and how intensively to grow them. Essentially, the larger the crop base (on any eligible commodity crop such as corn, wheat or cotton), and the larger the proven per-acre yield of any such commodity crop, the larger the payment received by the individual producer. These two variables have acted as direct incentives for farmers to establish relatively large program crop acreage bases, to maintain those established bases at levels consistent with individual farm plans and farm program strategies, and to generate maximum yields on those acres, in part through intensive use of synthetic fertilizers and pesticides. Moreover, compared to crop–livestock operations, wherein at least a portion of certain commodity crops such as corn may be fed to farm animals, it is somewhat easier to prove crop yields per acre in monocultural cropping systems. In the latter case, crops are marketed through local elevators or other commercial outlets, thus providing farmers with weight slips as proof of yield.

Finally, the accelerating wave of farm consolidations and other changes in US farm structure in the years during and following World War II[133] continue to have a negative impact upon contemporary debates regarding the nature of modern organic farming. During this transitional period, the number of farmers who left the farm in search of employment in nearby towns and villages (even large cities) increased sharply. Employment opportunities outside of agriculture expanded rapidly after the War, and the prospect of 40-hour work weeks, paid vacations and a regular pay check appealed to many farmers, especially when compared to the financial uncertainty and endless work associated with the small, confining, relatively primitive crop–livestock farming enterprises characteristic of that era in the US agricultural heartland. During this period, the now familiar corn–soybeans (and Miami) crop rotation, often the subject of light banter around today's rural Midwestern coffee shops, would have seemed fanciful. The lingering images from this period of large numbers of small-scale farmers leaving the farm at a time when much of agriculture was still relatively 'organic,' when such systems were being replaced with the chemical technologies that later would come to dominate American agriculture, have continued to distort perceptions of modern organic farming. The reluctance of conventional agriculture to acknowledge the scientifically documented agronomic, ecological and performance characteristics of contemporary organic farming, or to consider ways in which these modern systems could be more widely and productively integrated into the overall structure of American agriculture, continue to pose an important political barrier to the expansion of organic farming in the US, as well as in many other regions of the world.

Closing Reflections on the Evolution of Organic Agriculture in the US

As noted throughout this retrospective, organic agriculture in the US has changed dramatically over the past three decades. Thirty years ago few would have predicted that the meaning, image and practice of organic farming would have evolved so completely into a market-driven, legally defined production system, and that companies such as WalMart and Costco would be marketing certified, organically grown products. Furthermore, in 1980, predictions that these products would bear a certified label of authenticity from USDA would have been seen as delusional. Similarly, the development of formal research programs within USDA and the land-grant university system of direct relevance to organic agriculture—programs that, as discussed earlier, are now approaching fairly substantial levels of support—would have seemed equally unlikely. In the early 1980s a top USDA science administrator confidently predicted that there would never be an organic research program in the Department. Conventional agricultural scientists of the period apparently believed that both organic and conventional farmers

were well served by much past and current agricultural research [p. 28][134].

Successes of the kind noted throughout this account would seem to suggest that efforts by its opponents to halt the growth of organic farming have failed, and in some important respects, they did fail. Organic agriculture now represents a well-established, legally defined, and popular farming and food industry. That industry, however, bears only slight resemblance to the meanings and purposes attached to organic farming in the years surrounding publication of the 1980 USDA *Report and Recommendations on Organic Farming*[9]. Clearly, at that time, the emphasis among proponents of organic agriculture was focused primarily on the potential contributions of these systems to address the broad environmental, energy and financial pressures building throughout American agriculture, not upon the structure, growth and definition of certified organic farming systems. Certification programs then were in their infancy and the marketing infrastructure for organically grown food was only beginning to find its way into the mainstream. For many within conventional farming circles, the imagery of these fledging institutions reinforced the belief that organic agriculture was irrelevant to the broader needs of US agriculture, and that organic technologies were best suited for backyard gardeners, roadside stands, and as some said disparagingly, 'little old ladies in white tennis shoes.' Overcoming this negative and distorted imagery may now be seen as one of organic farming's most important achievements over the past three decades.

The successful commercial (and to some extent symbolic) transformation of organic farming notwithstanding, it seems important to ask why organic farming advocacy appears to have been far less successful in its efforts to foster the wider integration of organic technologies into conventional farming systems, the primary intent of many early proponents, including congressional sponsors of organic agriculture policy initiatives and participants involved in the two major scientific reviews of that period[9,70]. Roughly 1% of US farm and ranchland is managed using organic methods, according to the latest figures from USDA's Economic Research Service[109]. What accounts for this strikingly low percentage?

Several possible explanations come to mind. First, these data regarding the percentage of US farm and ranchland under organic management refer only to certified systems. Second, as noted previously, major political, ideological and technological developments over the past several decades have clouded efforts to define what constitutes a sustainable agriculture. Three decades ago organic-type technologies (such as long-term rotations including legumes and other green manure crops, along with integrated livestock operations) were widely viewed as essential features of a sustainable agriculture. Improved soil, water and air quality, enhanced wildlife habitat, soil erosion control, energy conservation, safer food and rural economic vitality were often said to flow from these kinds of reduced-chemical systems. Today, however, proponents of these traditional organic methods and systems can no longer lay exclusive claim to sustainability. Conventional agriculture has argued successfully that major features of its systems, such as conservation tillage, precision agriculture, biotechnology, less toxic pesticides and maximum yields, represent the modern elements of a sustainable agriculture. Clearly, the politics of sustainability have undermined efforts by proponents of organic farming to extend the reach of organic technologies more broadly throughout all of agriculture. As a result, organic agriculture has come to symbolize certified systems associated largely, if not exclusively, with the organic foods marketplace. In those locations and in those instances where organic farming techniques are being integrated into otherwise conventional farming enterprises, they will almost certainly be called something else, making it difficult, if not impossible, to determine the extent to which non-certified organic methods are being more widely used throughout US agriculture.

Third, as we have seen throughout this retrospective, symbolism and linguistics have often played crucial roles in the politics of organic agriculture, creating both positive and negative consequences for the industry. While many conventional agriculturists continue to reject and disparage organic farming, distorting its image and limiting its broader application, the American consumer has enthusiastically embraced organic products and much of its ideology. For most consumers of organic products, the symbolism and technology of organic farming are highly appealing, and while such consumers may not be steeped in the history and traditions of organic agriculture, the word organic itself has come to represent and project positive images and important personal meanings. Most consumers of organic foods and other organic products believe they know what organic means, and that is enough for most of them.

Finally, with respect to the issue of incorporating organic methods into conventional farming systems, proponents of organic agriculture may have had more success than is generally recognized. For example, analyses included in the 2010 NRC report on sustainable agriculture would seem to suggest the kinds of production alternatives seen as valid elements of a sustainable agriculture among the elite ranks of US agricultural scientists [Chapter 5][36]. While devoting only 12 pages of this chapter to organic farming systems *per se*, the NRC Committee devoted an additional 16 pages to such topics as integrated crop–livestock systems, management-intensive rotational grazing systems and low-confinement integrated hog-producing systems (28 pages in total), all in a 48-page chapter (including 10 pages of references) entitled, 'Examples of farming system types for improving sustainability' [pp. 221–269]. Only the most determined opponents of organic agriculture are likely to argue that these system types do not represent legitimate production options long associated with idealized models of organic

farming systems. Meanwhile, as long as the science, ideology and politics of American agriculture tend to limit use of the word organic to certified, market-driven systems, organic adherents may have to accept the fact that other terms will be used to describe many of organic farming's long-standing agronomic methods and principles, and perhaps even some aspects of its ideology as well.

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Comparing attitudes and characteristics of organic, former organic and conventional farmers: Evidence from Ireland

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Abstract

Despite an overall growth rate of the organic farming sector in the European Union, a considerable number of farmers cease organic production each year. Given the commitment of many European governments to increase the size of their organic farming sectors, reducing the rate of withdrawals from organic production may be an easier option than attracting new farmers into organic farming. In order to reduce the rate of withdrawals, knowledge about those farmers is required. However, to date, little is known about farmers who adopt and subsequently abandon organic farming. This study attempts to fill this gap in the literature by comparing and contrasting the farm and personal characteristics of organic, former organic and conventional farmers. To this end, primary data from 596 Irish cattle and sheep farmers are utilized. Overall, the findings reveal significant differences between the three groups. More specifically, organic farmers are found to be the most environmentally aware farmers, who also rate information gathering as more important than the remaining two groups. Organic farmers are younger, better educated and more likely to be women than conventional farmers. Former organic farmers stand out to be the least risk averse group and also express lower environmental awareness than organic farmers. Conventional farmers are found to be the most profit oriented and least environmentally aware group. In addition, this group farms more intensely stocked enterprises than the remaining groups. The paper concludes with a discussion of some policy recommendations aimed at increasing the size of the organic sector.

Key words: organic farming, former organic farmers, attitudes

Introduction

Organic production contributes to food safety and environmental protection, as it prohibits production with synthetic inputs, such as manufactured pesticides, artificial fertilizers and genetically modified organisms. For many farmers these attributes are an important motivation for conversion[1]. In addition, availability of subsidy payments and price premiums for organic produce provide economic motivation for conversion. However, there are also a number of barriers in switching to organic farming. For example, organic farming is an information intensive farming method that requires significant learning and changes in the farming system[1]. In addition, there are a number of risks associated with the uptake of organic agriculture, such as market and production risks[2]. Hence, the conversion to organic farming is a challenging process that depends on a variety of factors encompassing economic and non-economic determinants. Diverse motivations for conversion to organic farming, yet high learning costs and risks associated with organic farming, suggest that farmers with certain characteristics may be more likely to convert. However, not all conversion decisions result in long-term organic production as suggested by an over 7% rate of ceased organic producers in the European Union (EU) in 2005[3]. Despite large fluctuations in the organic sector with many farmers adopting and abandoning organic production each year, the organic sector in the EU has increased over the past 10 years, mainly due to policy support and market demand for organic products[4]. Given the commitment of many European governments to increase the size of their organic sectors and considering the large withdrawal rate from organic agriculture, it seems important to implement measures to prevent organic farmers from ceasing production rather than focusing on recruiting new farmers[5]. However, in order to decrease the number of farmers abandoning organic farming, more information about organic, former organic and conventional farmers is required. This study addresses this issue by answering the

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following research questions: what are the characteristics of farmers who successfully adopt organic farming and, more importantly, do these farmers differ from farmers who subsequently ceased organic production and from farmers who do not adopt at all?

The comparison of organic and conventional farmers has attracted considerable attention in the literature. Consequently, several studies have examined the characteristics and attitudes of organic farmers[6–11]. Organic farmers generally differ in their household and farm characteristics from their conventional counterparts: organic farmers are younger, better educated, more likely to be women and from an urban background[7]. Organic farms are often smaller in size with a lower stocking density, although there is a recent trend of larger farms converting to organic farming[6,7]. In terms of personal characteristics and attitudes, organic farmers express a higher level of environmental awareness[9,11,12], are less motivated by economic reasons[1,6] and are generally less risk averse than their conventional counterparts[13]. Furthermore, organic farmers prefer different information sources than conventional farmers[14]. For example, it has been argued that organic farmers find that conventional extension services are not particularly helpful[6].

In contrast, little is known about farmers who subsequently abandoned organic farming and how these farmers differ from organic and conventional farmers. Although, there is a general paucity of studies focusing on former organic farmers, few studies have investigated the reasons for withdrawal. For example, economic reasons such as market access and cost issues, agronomic problems, personal circumstances and regulations such as certifications and inspections were identified to be the main reasons for subsequently abandoning organic production[3,4,6]. In addition, farmers who entered with an economic perspective were found to be more likely to cease organic production at a later stage[6]. Nevertheless, information about farm and personal characteristics of these farmers is largely absent from the literature.

In fact, to date no earlier studies have compared the attitudes and characteristics of organic, former organic and conventional farmers. The present study aims to fill this gap by comparing farm and household characteristics as well as attitudes between organic farmers, farmers who subsequently left organic farming (termed ex-organic farmers thereafter) and conventional farmers. This information has the potential to improve government intervention to promote the adoption of organic agriculture among conventional farmers, while simultaneously reducing the number of subsequent withdrawals from organic production.

The Irish Organic Sector

Against the backdrop of an ailing macro economy, the Irish government published an ambitious plan for the agricultural sector in July 2010[15]. The plan is aimed at increasing the value of the agricultural sector's output, with a view to the Irish agriculture and food industries playing a key role in the overall recovery of the Irish economy. The report sets a target for increasing the value of primary agricultural output by 33% by 2020, relative to the average position in the 2007–2009 period. The sector level goal is supported by a number of detailed targets for the key agricultural sub-sectors. In terms of organic farming, the report sets a target to increase the organic farming sector to 5% of the agricultural land.

Currently, the Irish organic sector is small, occupying just over 1% of the agricultural area. In comparison, 4.7% of the agricultural area in the EU is under organic farming[16]. However, recent figures indicate that the Irish organic sector is a growth sector. For example, over the years 2006–2010 there has been a consistent increase of 8% per annum in organic farm numbers and there were 1386 Irish organic farms in 2010 [DAFM (Department of Agriculture, Food and the Marine), pers. comm., 2010]. Despite an overall growth rate of the sector, many farmers ceased organic production. For example, more than 200 farmers left organic farming between 2003 and 2006. Organic farmers in Ireland are most likely to leave organic farming after a 5-year-period[17]. This is due to the fact that organic subsidy payments are based on a 5-year contract and leaving the scheme early results in the requirement to pay back the subsidies received.

The Irish government has supported organic farming since June 1994 with the introduction of the Rural Environment Production Scheme in response to regulation (EEC) 2078/92. In addition to the availability of supply side subsidy payments, which are among the highest for EU Member States, demand side market opportunities exist for Irish organic red meat, in particular, export opportunities to the UK and Germany[15]. However, in line with the economic downturn, domestic sales of organic food have decreased over the past few years. Although the decline of organic food sales has been more severe with a decline in value of 16% between 2009 and 2010, the decline of organic food sales has leveled off to a 1% decline in value between 2010 and 2011[18]. However, according to industry experts, organic farming can still be an economically attractive option for producers[18].

The small scale of the Irish organic sector is somewhat surprising, given that the typical conventional systems of beef and sheep production in Ireland are generally extensive and mainly grass-based[17]. Therefore, many beef and sheep farmers could easily switch to organic production with relatively little entry cost and alterations in farm management or agronomic practices[19]. Hence, it is not surprising that the majority of organic farmers (80%) in Ireland are engaged in cattle and/or sheep farming. In contrast, the Irish organic dairy sector is very small, at about 20 dairy farms. The generally good return from dairying reduces the incentive for farmers to convert

Table 1. Definition of variables.

Variable name	Variable description
Farm size	Utilizable agricultural area of the farm measured in hectares
LU/ha	Livestock units per hectare
Off-farm job	If the farm operator has an off-farm job = 1, otherwise = 0
Age	Age of the farmer in years
Gender	Gender of the farm operator, women = 1, otherwise = 0
Higher education	If the farmer has higher education (second level or higher) = 1, otherwise = 0
Info advisory	Frequency of consultation with a farm advisor, attendance at information events and agricultural training courses, divided by three
Info media	Frequency of using magazines/press, TV/radio and the Internet as a source of farming information, divided by three
Knows another organic farmer	If the farmer knows another organic farmer = 1, otherwise = 0
Environmental attitude	Higher value = higher level of environmental concern
Profit orientation	Higher value = higher profit orientation
Risk attitude	Higher value = more risk averse
Information gathering attitude	Higher value = higher interest in information gathering

and, although Irish dairy farming is mainly grass based, dairy farms are managed in a more intensive way than drystock farms, thus making conversion more difficult. More importantly, there is only one main organic processor handling most of the organic milk, which implies that there are fundamental logistical difficulties in milk collection and processing. The second biggest organic sector is the horticultural sector, with about 300 growers. However, of these farms, there are only about 20 main growers that manage more than 6 ha [DAFM (Department of Agriculture, Food and the Marine), pers. comm., 2010]. This study focuses on drystock farmers, since the majority of organic farms can be found in this category. In addition, it is assumed that the decision of dairy and horticultural farmers to enter or exit the organic sector is different from the decision of drystock farmers, mainly due to different market conditions.

Methodology

Survey design and hypotheses

A questionnaire was developed which aimed at gathering information on farmers' attitudes and characteristics. The questionnaire consisted of several sections: (1) farm characteristics; (2) household characteristics; (3) frequency of information use; and (4) attitude statements regarding the environment, risk, profit motivation and information gathering.

All included attitude scales were measured by means of a number of statements, since attitude scales derived from a series of statements are regarded as superior to attitude scales derived from single questions[20,21]. The respondents were asked to agree or disagree with each statement on a 7-point scale ranging from −3 (= disagree very strongly) to +3 (= agree very strongly). In total, 35 statements were included in the survey. Some of the statements were adopted from the literature, but adjusted to Irish farming conditions. In order to avoid the respondents automatically choosing the same answer to consecutive statements and to keep their attention, statements for the same attitude scale were randomly scattered within all statements. In addition, positive- and negative-phrased statements were used, which means that seemingly contradictory statements were employed to assess farmers' attitudes as accurately as possible. In order to get the same meaning for all labels, negative statements were then recoded for statistical analysis. Finally, prior to conduction of the quantitative survey, the questionnaire was piloted with 20 farmers and the wording was adjusted based on the feedback received.

Table 1 provides an overview and description of the variables assessed in the survey. In terms of frequency of information use, the variables, info advisory and info media serve as a proxy to capture information use of the farmer. Info advisory measures the frequency of consulting a farm advisor, attending an information event or agricultural training course in the past 12 months divided by three. Info media measures how frequently the farmers used magazines/press, TV/radio or the Internet as a source for farming information in the past 12 months, also divided by three. Guided by the literature, statements in relation to the following attitudes are included: environmental attitude, profit orientation, risk attitude as well as attitudes toward information gathering[8,9,11,22].

Overall, the survey is designed to address the aforementioned research questions: what are the characteristics of farmers who successfully adopt organic farming, and more importantly, do these farmers differ from farmers who subsequently ceased organic production and from farmers who do not adopt at all? More specifically, given the different choices made by farmers, significant differences in the farm and household characteristics (Hypothesis 1) as well as attitudes (Hypothesis 2) between conventional, organic and ex-organic farmers are expected. In addition, more precise hypotheses are tested in relation to specific attitude scales. For example, it is hypothesized that farmers who express a high level of environmental awareness are more likely to adopt and stay in organic farming. Therefore, it is expected that organic farmers state a higher level of environmental awareness than conventional and ex-organic farmers

(Hypothesis 3). Given the finding that organic farming is often a lifestyle choice[1], it is hypothesized that organic farmers are less profit oriented than ex-organic and conventional farmers. In particular, ex-organic farmers are expected to be more profit motivated than organic farmers, as their adoption decisions have previously been found to be more economic driven[6] (Hypothesis 4). The adoption of organic farming entails a number of risks[13], therefore it is hypothesized that organic farmers are less risk averse than conventional farmers, but ex-organic farmers are expected to be the least risk averse group as they are willing to try new farming methods (Hypothesis 5). Finally, due to the importance of information on technology adoption in general and the fact that organic farming is an information intensive farming technique in particular[1], it is expected that organic farmers express a higher level of information gathering attitude than conventional and ex-organic farmers (Hypothesis 6). For example, more information on the technical aspects and marketing of organic produce could contribute to fewer exits from organic farming[6], as more information gathering may lead to better informed decisions.

Data

Data collection was administered as follows: complete address lists as of January 2008 were available for organic and ex-organic farmers from the Irish organic certification bodies (Irish Organic Farmers and Growers Organization and Organic Trust Ltd). A questionnaire was sent to each farmer on the list. Following an announcement of the survey in the Irish Farmers' Journal newspaper and one reminder letter, a response rate of 40% from the organic and 22% from the ex-organic farmers was achieved. A farmer was classified as organic if the farm was registered as organic or in conversion with the Irish Department of Agriculture, Food and the Marine in 2008, whereas a farmer was classified as ex-organic if the farm was registered as organic or in conversion at some point in the past.

Data for the conventional farmers were collected through Irish National Farm Survey (NFS) farms[23]. For this analysis, a subsample of the NFS farms was used and the majority of data were received from a supplementary survey (i.e., the previously described survey). In general, the NFS was established in 1972 and has been conducted on an annual basis since then. The NFS is collected as part of the EU-Farm Accountancy Data Network (FADN), providing a representative sample of Irish farms. Overall, there are approximately 1100 in the survey each year, representing a farming population of 110,000 farms.

After restriction of the analysis to drystock farms (i.e., farms with cattle and/or sheep), the final sample consisted of 596 farmers with the following breakdown: 341 organic, 50 ex-organic and 164 conventional farmers. This study focuses on drystock farms, since significant numbers of organic farms, necessary for a quantitative analysis, can be found in this sector.

Statistical analyses

Principal component analysis (PCA) with orthogonal (varimax) rotation was employed to the attitude statements as it reveals the underlying structure of the data and reduces dimensionality. That is, PCA was applied to empirically confirm whether each statement has the anticipated meaning, i.e., loads on the respective component. Statements were retained if they had loadings near or above 0.6 on one component and 0.2 or less on all other components[22]. This procedure reduced the number of statements to 23, as the remaining statements showed loadings on more than one component and are thus not pure measures of any one attitude scale. The final PCA confirmed the hypothesized four attitude scales, when retaining principal components with eigenvalues greater than one[24]. The four principal components explained 54.5% of the variance of the statements. This exceeds the minimum adequacy measure, as in some cases 50% of the explained variance can serve as a sufficient summary[25]. Each attitude scale was then computed as the mean of the original scores of the respective statements. Internal consistency of the attitude scales was measured with Cronbach's α.

Next, the sample was divided into the three previously defined farmers' groups (i.e., organic, ex-organic and conventional farmers). Differences between the three groups were assessed using analysis of variance for continuous variables and Chi-square statistics for comparisons of frequencies of categorical variables. Direct comparison between any two groups was conducted with t tests for continuous variables or Chi-square statistics for categorical variables.

Results and Discussion

Comparison of farm and household characteristics

The farm and household characteristics of the three groups are shown in Table 2. The mean values are reported along with the results of statistical tests of significant differences between the three groups. Statistical test results of differences between any two groups are included in the text. Overall, the three groups differ significantly with respect to the reported farm and household characteristics.

Conventional farmers have larger ($t=-7.21$; $P=0.00$) and more intensely stocked ($t=-6.89$; $P=0.00$) farms than their organic and ex-organic counterparts. Initially, organic agriculture was more likely to be adopted by smaller and more extensively farmed enterprises[7], but there has been a recent shift to larger and more commercially oriented farms converting to organic

Table 2. Farm and household characteristics of farmer groups.

Characteristic	Organic farmers $n=381$	Ex-organic farmers $n=50$	Conventional farmers $n=164$	Difference
Farm size	35.47 (23.56)	29.45 (38.49)	45.79 (39.90)	*
LU/ha	0.82 (0.44)	0.54 (0.45)	1.08 (0.49)	*
Off-farm job	0.44 (0.50)	0.66 (0.48)	0.33 (0.47)	*
Age	49.65 (10.63)	55.16 (9.78)	53.73 (11.32)	*
Gender	0.15 (0.35)	12.0 (0.33)	0.04 (0.20)	*
Higher education	0.73 (0.44)	0.72 (0.45)	0.65 (0.48)	**
Info advisory	0.99 (0.77)	0.65 (0.74)	0.69 (0.72)	*
Info media	3.56 (1.64)	2.85 (2.12)	3.46 (1.33)	**
Knows another organic farmer	0.87 (0.34)	0.82 (0.40)	0.35 (0.48)	*

Mean and standard deviation in parentheses, the column labeled. Difference indicates whether a significant difference exists in the means of variables of the three farmer groups based on an *F*-test or a χ^2 test. A χ^2 test was used on the following variables: off-farm job, age, gender, higher education and knows another organic farmer.
*,**indicates significance at the 99 and 95% level, respectively.

methods[6,9]; a trend that cannot be confirmed in this study. There is no significant difference in terms of farm size between organic and ex-organic farms ($t=1.08$; $P=0.27$), while organic farms have a higher stocking density than ex-organic farms ($t=4.13$; $P=0.00$).

Organic farmers are more likely to be engaged in off-farm work than conventional farmers ($\chi^2=6.45$; $P=0.01$), which could be due to the fact that organic farms are smaller than conventional farms. However, this is in contrast to the general finding that organic farming is more labor intensive[26], which interferes with engaging in off-farm work. It is also worth noting that the ex-organic farmers are the group with the highest proportion of farmers having an off-farm job ($\chi^2=11.83$; $P=0.00$). Generally, farmers involved in off-farm work have less time to spend on farming activities, which can initially complicate the ease of adjustment to organic methods. In addition, these farmers face higher opportunity costs of labor, which are especially important if the new method requires higher labor input[27].

In line with the previous findings[6,7], organic farmers are younger than ex-organic ($t=-3.71$; $P=0.00$) and conventional farmers ($t=-3.94$; $P=0.00$), while a higher proportion of organic and ex-organic than conventional farmers are women ($\chi^2=12.04$; $P=0.00$). In addition, organic and ex-organic farmers are also found to be somewhat better educated than conventional farmers ($\chi^2=3.92$; $P=0.05$), while no significant difference is evident between organic and ex-organic farmers.

In terms of frequency of information use, there are significant differences evident between the three groups. Organic farmers use advisory services more often than conventional farmers ($t=4.40$; $P=0.00$), while there is no significant difference between these two groups in terms of use of media information. Similarly, previous studies also argued that organic and conventional farmers use different information sources[14]. Organic farmers also utilize a higher number of information sources than ex-organic farmers, both in terms of information from advisory services ($t=3.06$; $P=0.00$) and information from the media ($t=2.75$; $P=0.01$). In this context, Rigby et al.[6] reported that some organic farmers in the UK had little experience and knowledge when converting to organic farming, which subsequently led to a withdrawal from organic production due to failure to make a living.

Whether or not the farmer knows another organic farmer is used as a proxy for social learning. As expected, organic and ex-organic farmers are more likely to know another organic farmer than conventional farmers ($\chi^2=162.58$; $P=0.00$). Other organic farmers are seen as an important source of information for farmers involved in converting to organic farming[11]. Furthermore, adopters are usually closely related through information networks, and high social integration can enhance adoption[28].

Results of principal component analysis

PCA confirmed the anticipated four attitude scales, which are then employed for further analysis. The statements related to each attitude scale are shown in Table 3 and described below. All attitude scales exhibit a Cronbach's α of close to or above 0.7.

Environmental attitude: this attitude scale comprises ten statements, which are related to environmental protection in agriculture and to organic farming in particular. A farmer who expresses a positive attitude toward the environment, i.e., is environmentally aware, generally agrees with statements such as 'It is important to be sensitive to the environmental impacts of farming by reducing input use on the farm.' Cronbach's α of this attitude scale is 0.87.

Profit orientation: this attitude scale consists of five statements, which measure profit orientation in farming methods, as well as in a wider context of the adoption of new technologies. A farmer who has a high score in statements such as 'It is important to make the largest possible profit from farming' or 'It is important to try new

Table 3. Attitude statements.

Environmental attitude
It is important to be sensitive to the environmental impacts of farming by reducing input use on the farm
The use of chemical inputs has a negative impact on the health of people and animals
It is important to take the environment into consideration, even if it lowers profit
It is important to farm in an environmentally friendly way
The impact of fertilizer run-off is worse than generally imagined
Organic farming is better for the environment than conventional farming
The use of chemicals in agriculture makes sense as long as it leads to an increase in profits (−)
Maximizing profits is more important than protecting the environment (−)
Organic farming is a fad (−)
Chemical fertilizers have no harmful effects; they promote high-quality production (−)
Profit orientation
It is important to receive the highest possible prices for the produce
It is important to make the largest possible profit from farming
It is important to try new ways to increase profit
Farming is about maximizing profits from farm business
To survive in farming, a farmer has to adapt to changing and new technologies
Risk attitude
Before applying different farming practices they first need to be proven on other farms
It is important to be cautious about adopting new ideas
It is important to avoid risky options in farm decision-making
Before adopting new ways of doing things it is important to see them working for other people
Information seeking attitude
It is important to discuss farming options with other farmers/friends
It is important to read about farming practices
It is important to have good contact with other farmers to discuss farm-related issues
It is important to visit other farms to look at their farming methods

All statements were measured from −3 to +3; re-coded statements are indicated by (−).

ways to increase profit' is considered to be profit oriented with regard to the farm enterprise. Cronbach's α of this attitude scale is 0.76.

Risk attitude: this attitude scale is measured by four statements, which relate to risk-taking behavior in farming. All of the statements are closely linked to the risk a farmer is willing to take when making farming decisions. A farmer who scores high in statements such as 'It is important to avoid risky options in farm decision-making' is regarded as risk averse. Cronbach's α of this attitude measurement is 0.69.

Information seeking attitude: this attitude scale consists of four statements. A farmer who scores high in this attitude scale agrees with statements such as the following: 'It is important to visit other farms to look at their farming methods' or 'It is important to read about farming practices.' Cronbach's α of this attitude scale is 0.79.

Comparison of attitudes

The scores of the attitude scales are reported in Table 4 along with the results of the statistical tests of difference between the three groups. Statistical test results of differences between any two groups are included in the text.

The three farmer groups differ significantly with regard to environmental attitude. Organic farmers express a higher level of environmental awareness than ex-organic ($t=1.87$; $P=0.06$) and conventional farmers ($t=20.72$; $P=0.00$). The latter result is in line with previous findings that organic farmers generally have a more positive attitude toward the environment than conventional farmers[8,12]. The finding that ex-organic farmers have a lower level of environmental awareness than organic farmers may be an indicator that this group was less committed to organic principles, a problem previously mentioned by Flaten et al.[9]. However, ex-organic farmers have a higher level of environmental awareness than conventional farmers ($t=-8.79$; $P=0.00$), suggesting that even when a positive attitude toward the environment exists, this does not guarantee long-term conversion. For example, profit motives may be stronger than environmental motives, even when the farmer states an awareness of environmental problems[29].

The three groups also differ significantly in terms of their attitudes toward profit. Conventional farmers express a higher profit orientation than their organic ($t=-4.05$; $P=0.00$) and ex-organic counterparts ($t=-4.57$; $P=0.00$), while there is no difference in the level of profit orientation between organic and ex-organic farmers ($t=1.41$; $P=0.16$). Organic farmers were thought to be less profit oriented than conventional farmers, but there is evidence in the literature that organic farmers'

Table 4. Attitude scales grouped by organic, ex-organic and conventional farmers.

Attitude	Organic farmers $n=381$	Ex-organic farmers $n=50$	Conventional farmers $n=164$	Difference
Environmental attitude	2.19 (0.72)	1.98 (0.88)	0.66 (0.95)	*
Profit orientation	1.58 (1.09)	1.36 (1.06)	1.96 (0.73)	*
Risk attitude	1.22 (1.08)	0.91 (0.98)	1.45 (0.86)	*
Information seeking attitude	2.02 (0.85)	1.81 (0.97)	1.62 (0.89)	*

Mean and standard deviation in parentheses, the column labeled difference indicates whether a significant difference exists in the means of variables of the three farmer groups based on an F-test.
* Indicates significance at the 99% level. Scales range from −3 (disagree very strongly) to +3 (agree very strongly).

conversion decisions became increasingly motivated by economic reasons[1,9]. Furthermore, farmers who subsequently withdrew from organic production have also been found to be more economically oriented[6], a finding that cannot be confirmed in this study.

There are also significant differences between the three groups with regard to risk attitudes. Organic and ex-organic farmers are less risk averse than conventional farmers ($t=-2.85$; $P=0.00$), which is in line with previous findings by Flaten et al.[13]. Organic producers are exposed to numerous sources of risks; for example, due to reduction in yields, restrictions in the use of pesticides and chemical fertilizers or locating new market outlets for organic produce, which provides an explanation that organic farmers are less risk averse. Comparing organic to ex-organic farmers, ex-organic farmers were found to be less risk averse ($t=2.08$; $P=0.04$). Depending on the risk attitude of a farmer, similarly perceived risks may have a different impact on adoption behavior[2]. Hence, a less risk averse farmer will adopt organic practices more easily than a more risk averse farmer, which may be one explanation that ex-organic farmers were found to be the least risk averse group. In addition, conventional farmers, who are found to be the most risk averse group in this study, may perceive the risks associated with organic farming as more severe than more risk neutral farmers, which could impede adoption.

The three groups also differ with regard to their information seeking attitudes. Conventional farmers rate information gathering as less important than the remaining two groups ($t=4.74$; $P=0.00$). Organic farming is an information intensive farming technique and successful conversion requires knowledge and information acquisition[1]. Gathering information can raise general awareness of organic farming and reduce uncertainty about the outcomes of the new method. The results also indicate that ex-organic farmers rate information gathering as slightly less important than organic farmers ($t=1.68$; $P=0.09$), which may be one explanation for subsequent withdrawal from organic farming as previously reported by Rigby et al.[6] for farmers in the UK. Ex-organic farmers' decisions may have been less informed than organic farmers' decisions, which may have caused problems and subsequent withdrawal.

Conclusions and Policy Implications

Despite an overall growth rate of the organic farming sector, a considerable number of farmers cease organic production each year. Nevertheless, little is known about farmers who adopt and subsequently abandon organic farming. By explicitly considering former organic farmers, the present paper addresses this gap in the literature. It compares and contrasts farm and household characteristics as well as attitudes of organic, former organic and conventional farmers.

Overall, the results of this study confirm significant differences between the three groups. More specifically, the three groups differ with regard to their farm and household characteristics (Hypothesis 1). Organic farmers are younger and utilize more information sources than the remaining groups. They have less intensely stocked farms than conventional farmers, while ex-organic farmers manage the least intensely stocked farms and have the highest proportion of farmers with an off-farm job. Conventional farmers manage the largest and most intensely farmed enterprises, are less likely to be women and to know another organic farmer.

The results also confirmed Hypothesis 2, as the three groups differ with regard to their attitudes. More specifically, organic farmers are found to express the highest level of environmental awareness, while conventional farmers are the least environmentally aware group (Hypothesis 3). Conventional farmers are more profit oriented than organic and ex-organic farmers, but the hypothesis that ex-organic farmers are more profit oriented than organic farmers cannot be confirmed (Hypothesis 4). Ex-organic farmers stand out as being the least risk averse group, while conventional farmers are the most risk averse group, thus confirming Hypothesis 5. Finally, conventional farmers rank information gathering as less important than the other two groups, while organic farmers express a higher level of information gathering attitude than ex-organic farmers (Hypothesis 6).

The results of this study have important policy relevance in terms of promoting an increase in organic conversion of agricultural producers. Environmental awareness of the farmer emerged to be an important

characteristic for long-term conversion. Thus, increasing farmers' environmental awareness could help to increase conversion to organic farming. However, environmental awareness itself is not enough to secure conversion, as indicated by the stated positive environmental awareness of farmers who left organic farming. It is likely that farmers who cease organic production encounter problems, which may be due to economic or technical reasons. In this context, information provision is a key factor for increasing the uptake of organic farming. However, this study has shown that conventional farmers rank information gathering as less important, thus effective means to disseminate information need to be identified to reach those farmers. It appears that conventional farmers mainly rely on the media and the Internet to receive information, which could be a potential channel to disseminate information on organic farming. Information provision is also important as a means to reduce risk. This is important as conventional farmers were found to be the most risk averse group, thus less willing to take risks in their farming decisions. However, advice and information about organic farming must clearly spell out the downside as well as the benefits. For example, it may be the case that in the absence of adequate information gathering many farmers converted abruptly, which ended in withdrawal from organic production for some. Therefore, it should also be the aim of the policymakers to reduce the number of farmers who subsequently drop out of organic farming, which may be easier than recruiting new farmers to organic farming. Consequently, it is paramount that information provision and advice are not only targeted toward potential entrants but also support existing organic farmers, especially in the first years of organic farming.

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Evaluation of Ethiopian chickpea (*Cicer arietinum* L.) germplasm accessions for symbio-agronomic performance

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Abstract

Chickpea (*Cicer arietinum* L.) is an economically and ecologically important food legume crop. Ethiopia has a large collection of chickpea germplasm accessions; but, it has not been extensively characterized for desirable sources of agronomic and symbiotic significance for use in breeding programs. A study was conducted at two locations (Ambo and Ginchi) in 2009/2010 to characterize and evaluate Ethiopian chickpea germplasm accessions for symbiotic and agronomic performance. One hundred and thirty-nine germplasm accessions were evaluated with 16 other genotypes including non-nodulating reference checks. Differences among genotypes, locations and genotype by location interaction effects were significant for a number of characters. A number of accessions better performing over the improved genotypes were identified for both symbiotic and agronomic characters. The amount of fixed nitrogen ranged from 13 to 49% in foliage, 30 to 44% in grain and 28 to 40% in total above-ground biomass. Grain yield performance varied from 31 to 70 g per 5 plants and seed size ranged from 82 to 288 g per 1000 seeds. For both symbiotic and agronomic characters, landraces were found to be overwhelmingly superior to introduced genotypes, except for seed size, where the best genotypes were all from exotic sources. The result indicated that Ethiopian chickpea landraces have better genetic potential for improving a number of symbiotic and agronomic characters over the varieties currently in use. Selection of best individuals within and among the accessions would be expected to be effective.

Key words: characterization, chickpea (*Cicer arietinum*), germplasm accession, symbiotic nitrogen fixation

Introduction

Nitrogen is the most essential nutrient required by plants in large quantities. Its deficiency is the major problem of crop production in many tropical and subtropical areas[1,2], particularly in East Africa[3] including Ethiopia[4,5]. Resource-poor farmers have striven to overcome the nitrogen deficiency problem since antiquity by integration of legumes in crop rotation systems[6], and by manuring and fallowing. Different studies in many parts of the world[7–11] including Ethiopia[12] have shown the importance of symbiotic nitrogen fixation not only to the legumes themselves but also to the cereals grown in association (as a mixed cropping) or rotation with them.

The amount of nitrogen fixed annually with symbiotic association is far more than the amount industrially produced[13,14]. Some estimates show that hundreds of millions of metric tons of nitrogen are symbiotically fixed each year[14,15]. At the farm level, nitrogen fixation with annual legumes may contribute 20–120 kg of nitrogen ha^{-1} in a season in the temperate region[16] and 15–120 kg ha^{-1} in tropical Africa[17].

Among the food legume crops, chickpea (*Cicer arietinum* L.) is a crop of manifold economic and ecological merit at the global level. Evidence indicates that chickpea fixes atmospheric nitrogen to the tune of 100 kg ha^{-1} [18,19] and contributes over 500,000 million tons of nitrogen every year to developing countries[20]. Ethiopia, being the first producer of chickpea in Africa in terms of area coverage, gets a significant amount of nitrogen fixation from the crop[21]. As in other legume crops, however, chickpea's effectiveness and efficiency to

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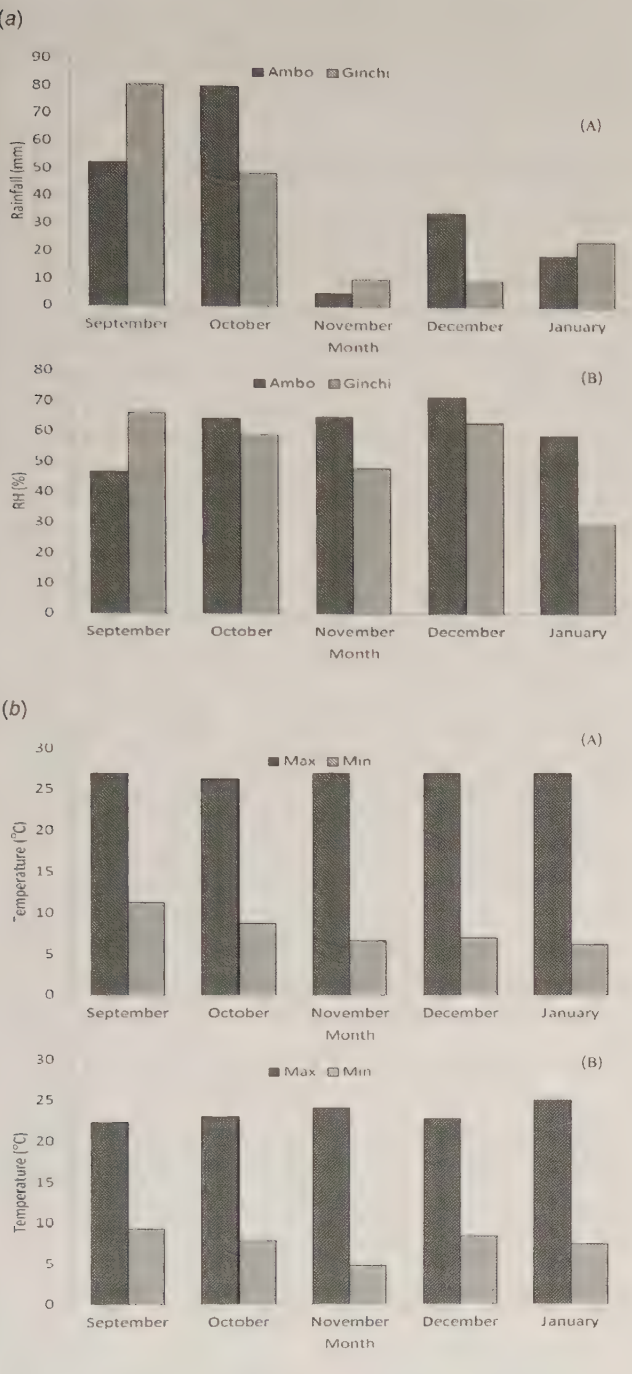

Figure 1. (a) Rainfall (mm) (A) and relative humidity (%) (B) at Ambo and Ginchi during the growing season. (b) Maximum and minimum temperatures (°C) at (A) Ambo and (B) Ginchi during the growing season.

fully realize its potential depends on the type of genotype, compatibility of the micro-symbiont and several environmental factors[22–24].

In most cases, farmers in Ethiopia do not use chemical fertilizers in chickpea production[25]. With the increasing price of nitrogen fertilizer and with growing environmental concern, selection of nutrient-efficient host genotypes with effective endosymbionts is a good alternative to overcome the problem of nitrogen deficiency. Efforts made to enhance nitrogen fixation through selection of better strains of *rhizobacteria* in Ethiopia have resulted in identification of many effective and competitive strains[26]. Nevertheless, development of better strains alone may not provide the required gains in productivity without compatible host genotypes[13,18,27,28]. Some reports indicate that host plants play rather a dominant role as compared to bacterial strain in enhancing symbiotic nitrogen fixation[20,29]. Even though genotypic variation for attributes of host symbiotic and agronomic significance have been reported in many legume crops including chickpea[1,30,31], for a variety of reasons, the role of host plants attracted little attention in Ethiopia and elsewhere[20,32].

Ethiopia has a large collection of chickpea germplasm but, apart from some observations in specific trials by microbiologists, mostly with a few improved varieties, no systematic assessment was made to exploit these gene pools especially for improving host symbiotic nitrogen fixation combined with agronomic performance. This study was, therefore, conducted to characterize and evaluate Ethiopian chickpea germplasm accessions and some varieties, and to identify desirable genotypes for symbiotic and agronomic performance.

Materials and Methods

Plant materials

In this study, a total of 155 chickpea genotypes were evaluated. They include 139 accessions collected from different regions of Ethiopia kindly provided by the Ethiopian Institute of Biodiversity Conservation (IBC), five improved genotypes from the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), eight originally introduced commercial cultivars released in Ethiopia and three genetically non-nodulating reference checks received from ICRISAT and the International Center for Agricultural Research in the Dry Areas (ICARDA). These chickpeas will be called 'genotypes' hereafter for experimental purpose. The passport description of the genotypes and the map of the areas of collection for the Ethiopian accessions are presented as online supplementary materials in Annexes A and B (at http://journals.cambridge.org/). All genotypes were rejuvenated during 2008/2009 under the same conditions at Ginchi to reasonably minimize initial variation due to differences in seed age and indigenous seed nitrogen contents[33].

The test environment

The experiment was conducted under field conditions at two locations (Ginchi and Ambo) in the central part of Ethiopia for 1 year during the main cropping season of 2009/2010 (September–January). The two locations are assumed to represent the major chickpea production areas

Table 1. Description of the test locations for geographical position and physico-chemical properties of the soils.

	Source of soil	
Parameter	**Ambo**	**Ginchi**
Latitude	09°00′N	09°00′N
Longitude	37°22′E	38°10′E
Altitude (m asl)	2225	2200
% Clay	70.00	65.83
% Silt	15.00	20.42
% Sand	15.00	13.75
Organic C (%)	1.53 (low)	1.30 (low)
N (%)	0.103 (low)	0.103 (low)
C/N ratio	14.85 (high)	12.62 (high)
P (ppm)[1]	18.07 (high)	4.49 (low)
K (Meq/100 g soil)	2.438 (high)	2.485 (high)
Ca (Meq/100 mg soil)	59.03 (high)	39.62 (high)
Mg (Meq/100 mg soil)	11.20 (high)	9.00 (high)
Na (Meq/100 mg soil)	0.70 (high)	0.61 (high)
SO_4 S (ppm)	5.23 (optimum)	5.62 (optimum)
Fe (ppm)	27.73 (high)	51.50 (high)
pH (1:1 H_2O)	7.23 (optimum)	6.18 (optimum)
EC (μS)[2]	650.00 (high)	547.33 (high)

[1]ppm, parts per million; [2]μS, micro Siemens. EC, electrical conductivity.

of Ethiopia. Climatic data of the two locations during the growing period were taken from Ambo and Holetta Research Centers (Fig. 1a and b). Soil samples from both locations were collected from the rhizosphere (top 20 cm) for physico-chemical characterization (Table 1).

Rhizobium *inoculant and inoculation*

An effective isolate of *Rhizobium* for chickpea, CP EAL 004, originally isolated by the National Soil Laboratory from a collection of Ada'a District of East Shewa Zone, Ethiopia, was used for the study. The isolate was found to be efficient in nodulation and symbiotic nitrogen fixation in previous studies[26]. The inoculum was received at the concentration of approximately 10^9 cells g^{-1} of peat carrier. The concentration and purity of the inoculum was confirmed in the Soil Microbiology Laboratory at Holetta Research Center immediately before planting. Seeds of all genotypes were coated with the inoculant at the rate of approximately 2 g of inoculum for 80 seeds using 40% gum Arabic as an adhesive.

Experimental design and layout

A randomized complete block design with four replications was used. A blanket basal application of phosphorus was made to all plots in the form of superphosphate (TSP) at the recommended rate (20 g for a single row of 4 m). Seed rate was 5 cm between plants and 40 cm between adjacent rows. The plot size was 1 row 4 m long. The genotypes were assigned to plots at random within each block. Nitrogenous fertilizer was totally omitted and all other crop management and protection practices were applied uniformly to all genotypes as required.

Shoot and grain nitrogen analysis

After 45 days of growth (shortly before flowering), five plants from each plot were carefully dug up and their roots washed free from soils with water running over a sieve for collection of nodules. Representative shoot and grain samples collected at 90% physiological maturity from each plot were oven-dried to constant moisture at 70°C for 18 h. The dry samples were ground to pass through a 1 mm mesh sieve to determine nitrogen using the Kjeldahl technique[34] at Holetta and Debre Zeit Soil Science Research Laboratories. The amount of total nitrogen accumulated from fixation in shoots and grains of the test genotypes was estimated by the difference method using a non-nodulating reference genotype PM 233. The N-difference method using a non-nodulating line as a reference plant was found to be both reliable and economical[35]. Protein contents of shoot and grain were determined by multiplying nitrogen percentages by the standard conversion factor of 6.25[34]. Based on the nitrogen contents, the following parameters were calculated:

$$\text{N fixed in shoot} = \frac{(\text{Nsfg} - \text{Nsnfg}) \times 100}{\text{Nsfg}}$$

where Nsfg is the amount of nitrogen in the shoot of the fixing genotype and Nsnfg is the amount of nitrogen in the shoot of the non-fixing genotype.

$$\text{N fixed in grain} = \frac{(\text{Ngfg} - \text{Ngnfg}) \times 100}{\text{Ngfg}}$$

where Ngfg is the amount of nitrogen in the grain of the fixing genotype and Ngnfg is the amount of nitrogen in the grain of the non-fixing genotype.

$$\text{N fixed in biomass} = \frac{(\text{N fixed in shoot} + \text{N fixed in grain}) \times 100}{\text{Nsfg} + \text{Ngfg}}$$

$$\text{N assimilation efficiency} = \frac{(\text{N fixed in grain} \times 100)}{\text{Nsfg} + \text{Ngfg}}$$

Grain N yield = Grain N content × grain yield
Shoot N yield = Shoot N content × shoot yield
Biomass N yield = Grain N yield + shoot N yield
Nitrogen harvest index (NHI) was estimated as

$$\text{NHI} = \frac{\text{Grain N yield}}{\text{Biomass N yield}}.$$

Data collection of symbiotic and agronomic characters

Data were collected either on a plot basis or from randomly selected five plants[36].

Table 2. Combined analysis of variance (over locations) for attributes of symbiotic and agronomic performance in 155 chickpea genotypes tested at two locations.

Character	Mean square			CV (%)
	L	G	G×L	
Symbiotic characters				
No. of nodules (NN, per 5 plants)	**	**	**	24.38
Nodule dry weight (NDW, mg per 5 plants)	**	**	**	14.69
Nodulation index (NI, mg g^{-1})	**	**	**	21.65
Shoot nitrogen content (SNC,%)	NS	**	NS	19.00
Shoot protein content (SPC,%)	NS	**	NS	19.00
Shoot nitrogen fixation (SNF,%)	**	**	NS	19.25
Grain nitrogen content (GNC,%)	NS	**	NS	9.53
Grain protein content (GPC,%)	NS	**	NS	9.53
Grain nitrogen fixation (GNF,%)	NS	**	NS	10.73
Above-ground biomass nitrogen content (BNC,%)	NS	**	NS	9.66
Biomass nitrogen fixation (BMNF,%)	**	**	NS	9.35
Fixed nitrogen assimilation efficiency (FNAE,%)	**	**	NS	10.38
Grain nitrogen yield (GNY, g per 5 plants)	NS	**	**	26.70
Shoot nitrogen yield (SNY, g per 5 plants)	**	**	**	19.55
Biomass nitrogen yield (BNY, g per 5 plants)	**	**	**	27.13
Nitrogen harvest index (NHI)	**	**	**	10.91
Agronomic characters				
Early vigor (SDWF, g per 5 plants)	**	**	**	25.61
Shoot dry weight ratio before flowering (SDWRF)	**	**	**	25.61
Days to 50% flowering (DTF)	**	**	NS	3.33
Days to 90% maturity (DTM)	**	**	NS	2.42
Grain filling period (GFP)	**	**	NS	5.71
No. of pods (NP, per 5 plants)	**	**	**	26.54
No. of seeds (NS, per 5 plants)	NS	**	**	28.30
Shoot dry weight at maturity (SDWM, g per 5 plants)	**	**	*	29.64
Shoot dry weight ratio at maturity (SDWRM)	**	**	*	29.55
Biomass weight (BMWT, g per 5 plants)	*	**	*	29.73
Harvest index (HI)	**	**	**	15.01
Grain production efficiency (GPE, g per 5 plants)	**	**	**	26.53
Biomass production rate (BPR,%)	**	**	**	19.69
Economic growth rate (EGR,%)	*	**	**	25.00
Thousand seed weight (TSW, g)	NS	**	**	18.39
Grain yield (YLD, g per 5 plants)	NS	**	**	24.57

**Highly significant ($P \leq 0.01$), *significant ($P \leq 0.05$), and NS = non-significant ($P > 0.05$).

Records of symbiotic characters were taken as follows: (1) number of nodules, (2) nodule dry weight, (3) nodulation index (nodule weight to shoot weight ratio), (4) shoot nitrogen and protein contents, (5) shoot nitrogen fixation, (6) grain nitrogen and protein contents, (7) grain nitrogen fixation, (8) above-ground biomass nitrogen content, (9) above-ground biomass nitrogen fixation, (10) fixed nitrogen assimilation efficiency, (11) shoot, grain and above-ground biomass nitrogen yields, and (12) NHI.

Agronomic characters recorded include: (1) early vigor (as shoot dry weight before flowering), (2) shoot dry weight at maturity, (3) shoot dry weight ratios (of nodulating to non-nodulating genotypes) before flowering and at maturity, (4) days to 50% flowering and 90% maturity, (5) grain filling period (the number of days from 50% flowering to 90% physiological maturity), (6) number of pods and seeds, (7) total above-ground biomass weight, (8) harvest index (proportion of grain to total above-ground biomass), (9) grain production efficiency (grain filling duration divided by duration of vegetative period and then multiplied by grain yield), (10) above-ground biomass production rate (above-ground biomass weight divided by days to 90% physiological maturity and then multiplied by 100), (11) economic growth rate (grain weight divided by grain fill duration and then multiplied by 100), (12) thousand seed weight and (13) grain yield.

Statistical analysis

Data based on nodules (number, weight and nodulation index) were log transformed to offset heterogeneity[37,38] for statistical analysis as suggested by Doughton[39]. Pooled analysis of variance was conducted to quantify

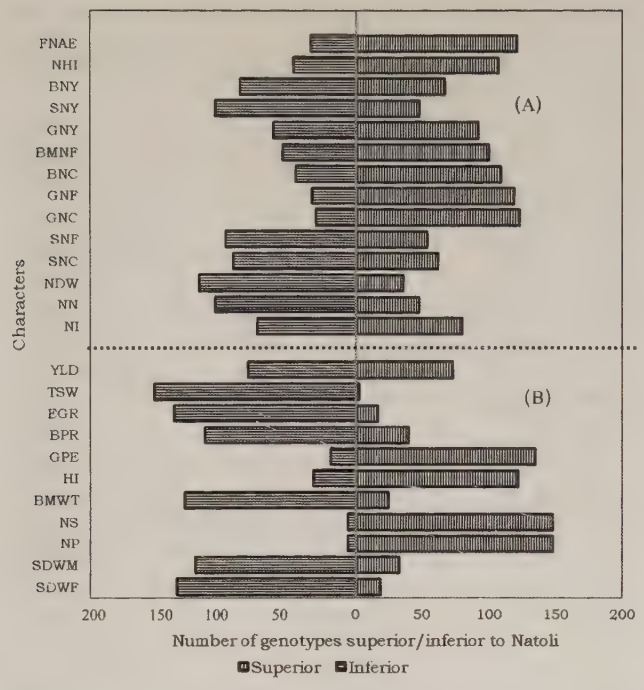

Figure 2. Proportion by number of the 155 chickpea genotypes superior and inferior to the recently released check, Natoli, for (A) symbiotic and (B) agronomic characters showing superiority of a number of landraces to the standard check (see Table 2 above for abbreviations of the characters).

the total variation among the genotypes using the following model of analysis of variance:

$$P_{ijk} = \mu + (b/l)i_k + g_j + l_k + (gl)_{jk} + e_{ijk}$$

where P_{ijk} is the phenotypic observation on genotype j in block i (at location k) ($i = 1, \ldots, B$, $j = 1, \ldots, G$, and $k = 1, \ldots, L$) and G, L and B are the number of genotypes, location and block, respectively, μ is the grand mean, $(b/l)_{ik}$ is the effect of block i (within location k), g_j is the effect of genotype j, l_k is the effect of location k, $(gl)_{jk}$ is the interaction effect between genotype j and location k and e_{ijk} is the residual or effects of random error.

Existence of significant differences among the genotypes, locations and genotype × location interaction effects were determined using the F-test. Mean separation was done using Duncan's multiple range test (DMRT) at 5% probability levels[38].

Results and Discussion

Description of the test locations

The two locations received more or less similar amounts of rainfall with different patterns of distribution, but Ambo was more humid than Ginchi (Fig. 1a). It was witnessed that the weather variables recorded did not deviate much from the long-term trends at both locations[40], indicating that the present findings will be reproducible over seasons.

The physico-chemical properties of the soils from the two test locations, Ambo and Ginchi, showed equally low levels of nitrogen contents (0.103%) but high levels of K, Ca, Mg, Na and Fe[41] with variable amounts. The levels of exchangeable cations were also high with pH values close to neutral. The level of soil phosphorus was high at Ambo and low at Ginchi (Table 1). Similar results were reported from previous analysis of soils at the same locations[42].

Symbiotic performances of the genotypes

Differences among the genotypes were significant for symbiotic nitrogen fixation and a number of associated characters (Table 2 and see supplementary material Annex C). The larger coefficients of variation (CV) values (> 20%) in many traits may be related to the production on residual moisture, where the crop was highly stressed, or a sample-based estimation of mean performances from only a few plants grown on small plots or both. Depending on host genotype, the amount of fixed nitrogen varied from 13 to 49% ($\bar{X}$ = 30%) in foliage, 30 to 44% ($\bar{X}$ = 36%) in grain and 28 to 40% ($\bar{X}$ = 34%) in total above ground biomass. The potential of fixation by the genotypes may be generally limited because of a shortage of soil moisture as the crop was grown with residual moisture. In Syria[43], for instance, fixation in winter-sown chickpea reached over 80–81%, where as spring-sown chickpea, where moisture was a limiting factor, fixed only 8–27%. The difference method of determination of the amount of nitrogen fixation may also underestimate the magnitude[42]. Protein contents of the shoot, grain and biomass, being derivative characters of plant tissue nitrogen, obviously followed the same pattern of variation as nitrogen contents. Other associated characters also showed wider ranges of variation.

Comparison of the test genotypes with a recently released variety, Natoli, and with the overall mean performances of eight released varieties (Shasho, Arerti, Worku, Akaki, Ejere, Teji, Habru and Natoli) identified a number of accessions with superior symbiotic performance including the amount of nitrogen fixation in shoot, grain and total above-ground biomass (Figs 2 and 4). The best 5% of the accessions for total (shoot + grain) nitrogen fixation include accession nos. 41222, 41029, 41021, 41074, 41075, 41129, 41320 and 41026.

These landraces could register additional fixation ranging from 18.52 to 23.88% over the standard check, Natoli, and 17.44 to 22.75% over the mean performance of the released varieties. These accessions also had the highest above-ground biomass nitrogen contents, which varied from 5.24 to 5.61%, the content of Natoli being 4.56%. As protein content follows the same trend as nitrogen contents, these accessions also contained the highest amount of protein in their biomasses (see supplementary table Annex C). There were some other genotypes that had better fixation of nitrogen, either in their shoots (e.g. 41103) or grains (e.g. 207734). Two

Table 3. Comparison of mean performances of 5% of the accessions selected for best symbiotic performance with Natoli, a recently released variety, and with mean performances of released varieties.

		Comparative advantage (% over)				Comparative advantage (% over)	
Accession No.	**Mean of selected accession[1]**	**Natoli**	**MRV[2]**	**Accession No.**	**Mean of selected accession**	**Natoli**	**MRV**
----------Shoot N fixation (%)----------				----------Grain N fixation (%)----------			
41222	48.67a	53.73	70.59	41021	43.54a	27.09	22.72
41026	47.29ab	49.37	65.76	41029	43.41ab	26.71	22.35
41074	46.05a–c	45.45	61.41	41222	42.79a–c	24.9	20.6
41103	45.63a–d	44.13	59.94	41074	42.48a–d	23.99	19.73
41075	45.04a–e	42.26	57.87	41320	42.07a–e	22.8	18.57
ICC 4973	42.85a–f	35.34	50.19	207734	42.05a–e	22.74	18.52
ICC 5003	42.80a–f	35.19	50.02	41129	42.04a–e	22.71	18.49
41320	42.11a–g	33.01	47.6	41075	41.75a–f	21.86	17.67
Natoli	31.66b–v	–	10.97	Natoli	34.26e–u	–	−3.44
MRV	28.53	−9.89	–	MRV	35.48	3.56	–
----------Biomass N fixation (%)----------				----------NHI----------			
41222	40.20a	23.88	22.75	41115	0.69a	18.97	21.05
41029	40.11ab	23.61	22.47	207150	0.67ab	15.52	17.54
41021	39.86a–c	22.84	21.71	231328	0.66a–e	13.79	15.79
41074	39.31a–d	21.14	20.03	207741	0.66a–e	13.79	15.79
41075	38.85a–e	19.72	18.63	209036	0.66a–e	13.79	15.79
41129	38.70a–e	19.26	18.17	207895	0.66a–e	13.79	15.79
41320	38.54a–g	18.77	17.68	219799	0.66a–e	13.79	15.79
41026	38.46a–g	18.52	17.44	41113	0.66a–e	13.79	15.79
Natoli	32.45e–y	–	−0.92	Natoli	0.58d–z	–	1.75
MRV	32.75	0.92	–	MRV	0.57	−1.72	–
----------Shoot N yield (g per 5 plants)----------				----------Grain N yield (g per 5 plants)----------			
41275	1.83a	37.59	45.24	41274	2.46a	35.91	44.71
41103	1.82ab	36.84	44.44	41111	2.34ab	29.28	37.65
41026	1.76a–c	32.33	39.68	207763	2.33a–c	28.73	37.06
207734	1.71a–d	28.57	35.71	207734	2.33a–c	28.73	37.06
41289	1.70a–e	27.82	34.92	207742	2.29a–d	26.52	34.71
41185	1.69a–e	27.07	34.13	ICC 19180	2.28a–e	25.97	34.12
41284	1.67a–f	25.56	32.54	41268	2.23a–f	22.65	30.59
41320	1.66a–g	24.81	31.75	41316	2.22a–g	22.65	30.59
Natoli	1.33a–o	–	5.56	Natoli	1.81a–p	–	6.47
MRV	1.26	−5.26	–	MRV	1.70	−6.08	–
----------Biomass N yield (g per 5 plants)----------				----------Fixed N assimilation efficiency (%)----------			
207734	4.05a	28.57	36.82	ICC 19180	90.61a	15.38	10.16
41274	3.87ab	22.86	30.74	41115	90.15ab	14.8	9.6
41275	3.80a–c	20.63	28.38	207659	89.74a–c	14.27	9.11
41185	3.80a–c	20.63	28.38	219799	89.03a–d	13.37	8.24
41111	3.75a–d	19.05	26.69	207150	88.74a–e	13	7.89
41284	3.70a–d	17.46	25	41277	88.10a–f	12.19	7.11
41103	3.69a–d	17.14	24.66	41113	87.79a–g	11.79	6.74
41289	3.68a–e	16.83	24.32	207894	87.10a–h	10.91	5.9
Natoli	3.15a–m	–	6.42	Natoli	78.53d–r	–	−4.52
MRV	2.96	−6.03	–	MRV	82.25	4.74	–

[1]Values sharing the same letter(s) or ranges of letters within the same column are non-significantly different; [2]MRV = mean of released varieties. NHI, nitrogen harvest index.

introductions from ICRISAT, namely ICC 5003 and ICC 4973, were also among the best 5% for shoot fixation. The best genotypes for NHI, with superiorities of 13.79–18.97% over Natoli and 15.79–21.05% over the mean performances of the released varieties, were also landraces. This contradicts the tendency that modern cultivars usually show better NHI than landraces[44].

The best assimilators of fixed nitrogen were accession nos. 41115, 207659, 219799, 207150, 41277, 41113 and 207894. A genotype introduced from ICRISAT as a

Table 4. Comparison of mean performances of 5% of the accessions selected for best agronomic performance with Natoli, a recently released variety, and with mean performances of released varieties.

		Comparative advantage (% over)				Comparative advantage (% over)	
Accession No.	**Mean of selected accession[1]**	**Natoli**	**MRV[2]**	**Accession No.**	**Mean of selected accession**	**Natoli**	**MRV**
----------No. of pods (per 5 plants)----------				----------No. of seeds (per 5 plants)----------			
41289	515a	94.34	105.18	41111	595a	144.86	146.89
41274	497ab	87.55	98.01	207658	575a	136.63	138.59
41215	486a–c	83.4	93.63	41185	566a–c	132.92	134.85
41284	485a–c	83.02	93.23	41274	556a–d	128.81	130.71
209091	480a–d	81.13	91.24	41215	556a–d	128.81	130.71
41015	471a–e	77.74	87.65	ICC 4948	541a–e	122.63	124.48
207563	466a–f	75.85	85.66	207764	535a–f	120.16	121.99
41114	464a–g	75.09	84.86	209084	535a–f	120.16	121.99
Natoli	265u–z	–	5.58	Natoli	243z	–	0.83
MRV	251	−5.28	–	MRV	241	−0.82	–
----------Biomass weight (g per 5 plants)----------				----------Harvest index----------			
41284	224.32a	32.55	45.1	231328	42.88a	29.59	34.21
41274	204.41ab	20.79	32.22	209093	42.58ab	28.68	33.27
207734	198.76a–c	17.45	28.56	209094	42.07a–c	27.14	31.67
41275	194.41a–d	14.88	25.75	41002	40.41a–d	22.12	26.48
Habru	191.06a–e	12.9	23.58	231327	40.27a–e	21.7	26.04
ICC 19180	188.92a–e	11.64	22.2	207764	40.12a–f	21.25	25.57
41185	183.47a–f	8.41	18.67	207741	40.08a–f	21.12	25.45
207563	182.83a–g	8.04	18.26	41115	39.47a–g	19.28	23.54
Natoli	169.23a–m	–	9.46	Natoli	33.09g–w	–	3.57
MRV	154.6	−8.65	–	MRV	31.95	−3.45	–
----------Grain production efficiency----------				----------Biomass production rate (%)----------			
207763	70.65a	63.69	57.17	41284	198.82a	37.65	47.06
41111	70.35ab	63	56.51	41274	181.47ab	25.64	34.22
41274	69.71a–c	61.52	55.08	ICC 19180	175.17a–c	21.28	29.56
207742	69.14a–d	60.19	53.82	207734	170.96a–d	18.36	26.45
41053	68.21a–e	58.04	51.75	41275	169.91a–e	17.63	25.67
209093	67.70a–f	56.86	50.61	Habru	169.65a–f	17.45	25.48
207658	67.57a–f	56.56	50.32	207743	162.38a–g	12.42	20.1
219800	66.70a–g	54.54	48.39	207563	161.98a–g	12.14	19.81
Natoli	43.16q–z	–	−3.98	Natoli	144.44b–n	–	6.83
MRV	44.95	4.15	–	MRV	135.2	−6.4	–
----------Economic growth rate (%)----------				----------Grain yield (g per 5 plants)----------			
41274	125.02a	18.6	34.65	41274	70.10a	30.76	42.22
ICC 19180	118.90ab	12.8	28.06	207763	66.05ab	23.2	34
207763	113.75a–c	7.91	22.51	41111	65.16a–c	21.54	32.2
41268	112.48a–d	6.71	21.14	207742	64.22a–d	19.79	30.29
231328	111.83a–e	6.09	20.44	231328	63.62a–e	18.67	29.07
41293	111.58a–e	5.85	20.17	207563	63.10a–f	17.7	28.02
41111	110.44a–f	4.77	18.94	41053	62.59a–g	16.75	26.98
207563	109.29a–g	3.68	17.71	212589	62.52a–g	16.62	26.84
Natoli	105.41a–l	–	13.53	Natoli	53.61a–t	–	8.76
MRV	92.85	−11.92	–	MRV	49.29	−8.06	–

[1]Values sharing the same letter(s) or ranges of letters within the same column are non-significantly different; [2]MRV, mean of released varieties.

non-nodulating check, ICC 19180, was found to be nodulating with best performance for grain nitrogen yield and assimilation efficiency of fixed nitrogen (Table 3). Whether a change in environment alone can induce nodulation of a genotype that is naturally non-nodulating in another environment needs to be sorted out in the future.

These are accessions with desirable attributes of both symbiotic and agronomic significance. For example, accession no. 41274 possessed both better symbiotic

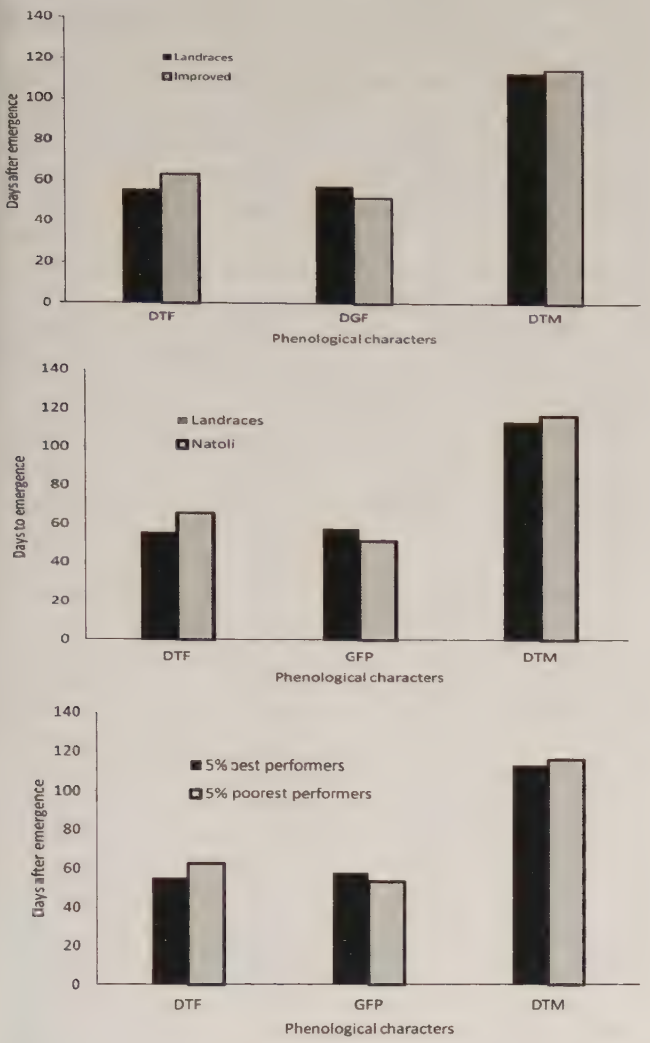

Figure 3. Comparison of phenological characters in 155 genotypes for days to flowering (DTF), grain filling period (GFP) and days to maturity (DTM), showing shorter relative periods of vegetative and longer grain-filling periods in landraces than in improved genotype.

(grain and biomass nitrogen yields) and agronomic (pod and seed setting, biomass weight, production efficiency, biomass production rate, economic growth rate and grain yield) attributes. Among the introductions, ICC 19180 demonstrated relatively better grain nitrogen yield and assimilation of fixed nitrogen with better biomass production and economic growth rates.

Comparison of nitrogen fixation patterns between modern cultivars and landraces does not appear to follow a simple trend as there are conflicting reports. Some found better nitrogen-fixing genotypes from among the old cultivars, landraces or wild relatives than commercial varieties[44,45]. In another study, field pea landraces introduced from Ethiopian to Germany were found to fix more nitrogen than a commercial cultivar[46]. A similar result was also reported in *Phaseolus vulgaris* in Austria[47]. Our experience with primitive forms of *Pisum sativum* contrarily showed superiority of improved cultivars

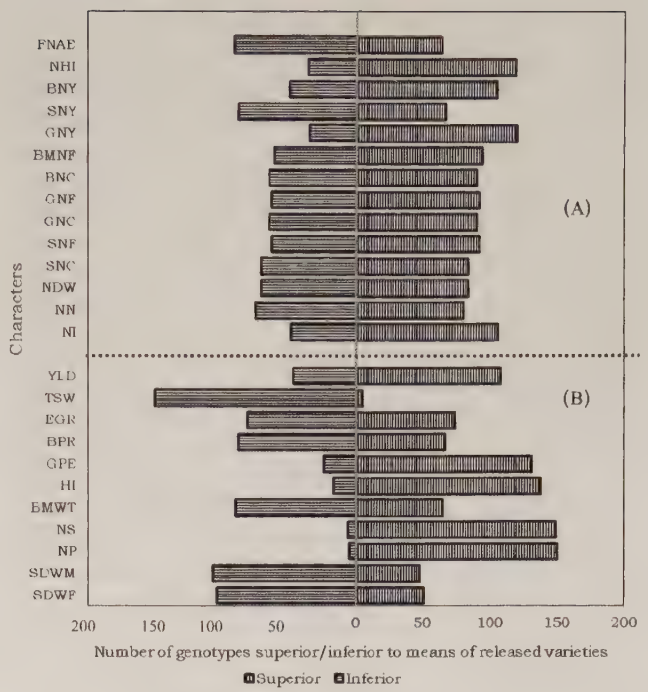

Figure 4. Proportion by number of the 155 chickpea genotypes superior and inferior to mean performances of all the released varieties for (A) symbiotic and (B) agronomic characters, showing superiority of a number of landraces to the standard check (see Table 2 above for abbreviations of the characters).

over the landraces[48]. In chickpea, both nodulation efficiency and grain yield were improved as the result of selection from commercial cultivars[1]. Therefore, specific tests for specific breeding materials, strain and environments may be needed to improve the selection process.

Agronomic performance of the genotypes

Differences among the genotypes were significant for a number of agronomic characters (Table 2). The comparison of the different genotypes with the recently released variety Natoli showed the superiority of a number of landraces for a number of agronomic traits (see supplementary table Annex D). Accordingly, the best 5% of the accessions for yield include accession nos. 41274, 207763, 41111, 207742, 231328, 207563, 41053 and 212589. These accessions recorded yield advantages of 16.62–30.76% over Natoli and 26.84–42.22% over the mean performance of the released varieties. There were many other landraces that were superior for many other traits. The improved cultivars that were originally from exotic sources might be more affected by moisture stress than the primitive landraces that have co-existed with the stress, but the detail will be discussed later. Experience with soybean (*Glycine max*) also showed that exotic of genotypes are usually lower yielding than domestic cultivars when released directly[49]. Nevertheless, no landrace was comparable to the improved genotypes for seed size (Fig. 2), the top 5% of genotypes for this trait being ICC 4918, ICC 5003, ICC 19180, Natoli, Teji, Ejere,

Table 5. Mean performances of 155 chickpea genotypes for attributes of symbiotic nitrogen fixation and agronomic performance at two locations in Ethiopia.

Character	Ambo	Ginchi	Mean
Symbiotic characters			
No. of nodules (NN, per 5 plants)	12.33b	14.06a	13.19
Nodule dry weight (NDW, mg per 5 plants)	683.39a	156.99b	420.19
Nodulation index (NI, mg g^{-1})	2.48a	0.38b	1.43
Shoot nitrogen content (SNC,%)	1.19a	1.17a	1.18
Shoot protein content (SPC,%)	7.41a	7.30a	7.36
Shoot nitrogen fixation (SNF,%)	35.77a	24.18b	29.97
Grain nitrogen content (GNC,%)	3.52a	3.51a	3.51
Grain protein content (GPC,%)	21.99a	21.92a	21.95
Grain nitrogen fixation (GNF,%)	35.74a	36.15a	35.95
Total biomass nitrogen content (BNC,%)	4.70a	4.67a	4.69
Total nitrogen fixation (BNF,%)	34.26a	32.22b	33.24
Fixed nitrogen assimilation efficiency (FNAE,%)	77.21b	83.35a	80.28
Grain nitrogen yield (GNY, g per 5 plants)	1.87a	1.83a	1.85
Shoot nitrogen yield (SNY, g per 5 plants)	1.30a	1.20b	1.25
Biomass nitrogen yield (BNY, g per 5 plants)	3.17a	3.03b	3.10
Nitrogen harvest index (NHI)	0.59b	0.61a	0.60
Agronomic characters			
Early vigor (SDWF, g per 5 plants)	30.78b	44.03a	37.4
Shoot dry weight ratio before flowering (SDWRF)	1.02b	1.74a	1.38
Days to 50% flowering (DTF)	55.00b	58.22a	56.61
Days to 90% maturity (DTM)	113.72a	114.41a	114.06
Grain filling period (GFP)	58.72a	56.19b	57.45
No. of pods (NP, per 5 plants)	388.26a	363.20b	375.73
No. of seeds (NS, per 5 plants)	423.72a	419.10a	421.41
Shoot dry weight at maturity (SDWM, g per 5 plants)	109.17a	102.57b	105.87
Shoot dry weight ratio at maturity (SDWRM)	1.55a	1.53b	1.54
Total biomass weight (BMWT, g per 5 plants)	155.16a	148.59b	151.88
Harvest index (HI)	34.63b	35.68a	35.15
Grain production efficiency (GPE, g per 5 plants)	57.1a	51.13b	54.12
Biomass production rate (BPR,%)	136.56a	130.07b	133.32
Economic growth rate (EGR,%)	90.47b	93.20a	91.84
Thousand seed weight (TSW, g)	113.21a	114.38a	113.8
Grain yield (YLD, g per 5 plants)	52.85a	52.20a	52.53

*Values within a row sharing the same letter are statistically non-significant.

Arerti and Habru, which are introductions either from ICRISAT or ICARDA.

The landraces make the majority of the top 5% performers to the improved introductions for many attributes. Some of them, such as accession no. 41274, have displayed superiority for grain yield, pod and seed setting, biomass dry weight and production rate, grain production efficiency and economic growth rate. Another accession, accession no. 207563, was also among the top performers for grain yield, economic growth rate and pod setting. A number of other superior accessions for multiple traits of agronomic significance, including grain yield, were also identified (Table 4).

Detailed physiological reasons for the superiority of the landraces over the improved genotypes may need future study. From our observations, the landraces had relatively shorter period of vegetative growth and longer grain-filling periods. The comparison of the 5% best yielders for phenological characters with the 5% poorest yielders may also show, at least in part, that the genotypes tested here differed in grain yield for a similar reason (Fig. 3). Ideotypes with the faster developmental switch to reproductive growth earlier in the growing season when the soil moisture level is still adequate might have a better comparative advantage to mobilize assimilates and use them more efficiently for reproductive growth. The same mechanism might have provided the landraces with adequately longer period of time for grain filling. A similar observation was made in Ethiopian fenugreek (*Trigonella foenum-graecum*) landraces as compared to a released variety[50]. On the contrary, improved genotypes showed delays in flowering; the consequence may be higher investment in vegetative growth and longer exposure of their reproductive growth to an end-of-season moisture stress. It may be implied, therefore, that landraces may have better structural and functional fitness to survive and reproduce under moisture deficit condition than the improved genotypes.

Effect of location

The two locations displayed significant differences for a number of symbiotic and agronomic characters. However, number and size of seeds, shoot and grain nitrogen and protein contents, grain and total nitrogen fixation, grain nitrogen yield and grain yield did not show marked differences between locations (Table 5).

The number of nodules per five plants was higher at Ginchi and lower at Ambo, but nodule weight was heavier at Ambo. As nitrogen fixation was also better at Ambo than it was at Ginchi, this may imply that weight of nodules may be more important (within a limit) for fixation than their mere number. Better fixation at Ambo may also be attributed particularly to the higher level of phosphorus in the soil since phosphorus is of paramount importance in fixation[22].

Genotype by location interaction effects

Genotype by location interaction effects were significant for a number of symbiotic and agronomic characters (Table 2). Significant genotype by location interaction effects were mostly a 'cross-over' type; i.e., interactions were associated with rank order changes among the genotypes (data not shown). This indicated that the two locations were distinctly different for some of the characters and that better genotypes at one location may not also be better performing at another. Even though the inheritance of the process of nodulation was considered to be relatively simple[13], the genetic control of the whole process of symbiotic nitrogen fixation is complicated due to its polygenic nature[51,52]. Plant breeding commonly involves dealing with only a single organism at a time and, while this itself is not simple, breeding for symbiotic nitrogen fixation demands dealing simultaneously with both the host plant and the strain, which interact differently between themselves and with the environment[18]. Most of the traits related to yield and agronomic yield components, nodulation and nitrogen yields showed significant genotype by location interaction. Fortunately, genotype by location interaction effects were non-significant for components related to plant tissue nitrogen contents, including the amount of fixation. This may indicate lesser sensitivity of traits for symbiotic nitrogen fixation to changes in the environment. In our previous study with primitive forms of *P. sativum* native to Ethiopia, we also found similar results[48]. Therefore, genotypes selected at one location for nitrogen (and hence protein) content and fixation levels may perform similarly in other locations.

Conclusions

The present study revealed that the Ethiopian chickpea landraces had considerable significance as sources of genotypes with desirable symbiotic and agronomic characters. Despite the important roles they could have played in chickpea–breeding programs, unfortunately, the potential of the Ethiopian chickpea landraces has not been properly exploited hitherto by the breeding efforts. Almost all of the released varieties currently under production in Ethiopia trace their genetic base to the introductions either from ICARDA or ICRISAT. The accessions selected here could serve as the basis for formulating an efficient scheme of multiple trait selection for both desirable symbiotic and agronomic characters. It can be expected that individual lines developed through selection from among the accessions identified here may result in even better performances than the 'mother' accessions themselves.

The past breeding strategy based on direct release of introduced genotypes has produced special cultivars that are substantially different from commonly grown landraces, particularly in terms of seed size and color. As far as a number of symbiotic and other agronomic merits are concerned, the Ethiopian chickpea landraces should constitute the predominant part in the genetic background of the breeding program. When the desired character does not exist in the available gene pool, as we indicated for seed size, screening of exotic germplasm becomes essential to identify good donor parents. Except for a few accessions, the majority of the landraces did not show a better combination of desirable symbiotic and agronomic characters, which may be of rare natural occurrence. In order to achieve varieties that combine many desirable symbiotic and agronomic attributes, therefore, there is a need to concomitantly incorporate many desirable traits from different sources into a single genotype through hybridization.

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Conservation agriculture systems for Malawian smallholder farmers: long-term effects on crop productivity, profitability and soil quality

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Abstract

Conservation agriculture (CA) systems are based upon minimal soil disturbance; crop residue retention and crop rotation and/or intercrop association are increasingly seen to recycle nutrients, increase yield and reduce production costs. This study examines the effects of CA practices on crop productivity, profitability and soil quality under the conditions encountered by smallholder farmers in two farming communities from 2005 to 2011 in Malawi, as part of the contribution to remedy a lack of supporting agronomic research for these relatively new systems. The drier agroenvironment of Lemu of Bazale Extension Planning Area (EPA) is characterized by sandy clay loam soils and lower rainfall. Here, CA showed positive benefits on maize yield after the first season of experimentation, with highest increases of 2.7 Mg ha^{-1} and 2.3 Mg ha^{-1} more yield in CA monocrop maize and CA maize–legume intercrop, respectively, than the conventional tillage in the driest season of 2009/10. In the high rainfall environment of Zidyana EPA (characterized by sandy loam soils), substantial maize yield benefits resulted in the fifth season of experimentation. Farmers spent at most 50 days ha^{-1} (US$140) producing maize under CA systems compared with 62 days ha^{-1}(US$176) spent under conventional tillage practices. In Lemu, both CA systems resulted in gross margins three times higher than that of the conventional control plot, while in Zidyana, CA monocrop maize and CA maize–legume intercrop resulted in 33 and 23% higher gross margins, respectively, than conventional tillage. In Zidyana, the earthworm population was highest (48 earthworms m^{-2} in the first 30 cm) in CA monocrop maize, followed by a CA maize–legume intercropping (40 earthworms) and lowest (nine earthworms) in conventionally tilled treatment. In both study locations CA monocrop maize and CA maize–legume intercrop gave higher water infiltration than the conventional treatment. Improvements in crop productivity, overall economic gain and soil quality have made CA an attractive system for farmers in Malawi and other areas with similar conditions. However, for extensive adoption of CA by smallholder farmers, cultural beliefs that crop production is possible without the ubiquitous ridge and furrow system and residue burning for mice hunting have to be overcome.

Key words: no-tillage, maize yield, net returns, residue retention, infiltration, biological activity, herbicides

Introduction

Achieving the Millennium Development Goal (MDG) on poverty reduction will be challenging in the southern African region where a majority of the population depend on agriculture for their livelihood[1]. In Malawi, agriculture is the mainstay of the economy, contributing nearly 35% of the gross domestic product (GDP). Typical cultivated land holding sizes are 0.2–3 ha and there is limited land area to expand agricultural production due to an increase in population growth[2]. The efficiency of crop productivity forms an essential component of improving food security. Maize is the major staple crop, occupying about 1.66 million hectares, translating to 80% of the land area under cultivation[3] and accounting for more than 80% of the population's caloric intake[4].

Over the past 25 years, average maize yields in Malawi remained low (Fig. 1) until 2005 when an ambitious

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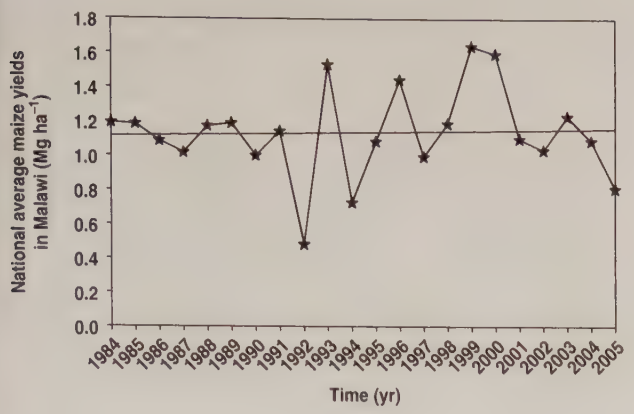

Figure 1. Average maize yields (t ha^{-1}) in Malawi from 1982 to 2005 (MoAFS, 2008[4]).

smallholder Farm Input Support Program (FISP) was initiated. When fertilizer inputs increased, average maize yields jumped from approximately 1.1 Mg ha^{-1} in the 2004/05 season to 1.6 Mg ha^{-1} in the 2005/06 season[5]. In the subsequent seasons, the estimated average maize yields were 2.6 Mg ha^{-1} (2006/2007), 1.6 Mg ha^{-1} (2007/2008), 1.7 Mg ha^{-1} (2008/2009), 1.8 Mg ha^{-1} (2009/2010) and 2.1 Mg ha^{-1}(2010/2011), respectively[5,6]. Some expressed concern about the sustainability of subsidized fertilizer and maize seed schemes, largely because of the high cost of inorganic fertilizer and the necessary budgetary support of the intervention[7,8], but their huge impact on grain yield is beyond debate.

Despite the possibility of technological solution and policy support, agricultural productivity is limited by biotic and abiotic factors as well as institutional and socio-economic constraints. For example, even when inputs are subsidized, the gap between the actual yield in Malawi ($\sim$ 1.2 Mg ha^{-1}) and attainable yield ($\sim$ 7 Mg ha^{-1}) is still very wide[9].

In many farming systems, owing to continuous cropping, soil organic matter (SOC) contents have diminished to unsustainably low levels and are an important cause of low water and nutrient use efficiency and systems productivity[10]. Intensive soil tillage using hand hoes coupled with insufficient organic matter return to the soil are perceived as a major cause of land degradation[11,12].

In Malawi, the ridge and furrow system, a farming method based on annually created raised seed beds, is labor intensive, reduces water infiltration due to 'hoe pans' and results in yield reductions over time[13]. These problems erode the benefits from crop genetic enhancement and further add to the increased risk of crop failure in times of frequent seasonal drought[14].

This calls for sustainable production systems with more efficient use of resources and minimal environmental impact, while preserving the natural resource base dedicated to agriculture[15].

Conservation agriculture (CA) is a sustainable cropping system that may help in reversing soil degradation, stabilizing and possibly increasing yield, and reducing labor time and producing a high net return. CA is based on three main principles: (1) minimum soil disturbance (i.e., direct sowing of crop seeds); (2) permanent soil cover with living or dead plant material; and (3) crop rotation or association with leguminous or cash crops for family use or sale[16]. CA systems practiced in southern Africa follow the general principle but other supporting management systems, such as manure, fertilizer, herbicides, early planting and row spacing, form part of the system. In most instances, use of herbicides is promoted within the CA package to control weeds, which become a nuisance especially in the initial years.

There are basically three different manual CA systems promoted and used in southern Africa besides animal traction (ripper tine and animal traction direct seeding systems) and tractor-drawn systems: the dibble stick, planting basins and jab-planters. Farmers in Malawi generally practice CA with the dibble stick, a pointed wooden stick, which aims at disturbing the soil as little as possible by only creating a planting hole where seeds are placed. Although planting basins and jab-planters are also promoted and have been tested, farmers in Malawi prefer the dibble-stick planting method because it is compatible with the traditional planting methods (i.e., planting the seed on the ridges is normally done with a pointed stick)[17].

The second method, used widely in Lesotho, Zambia and Zimbabwe, is based on manually dug planting basins[18–20]. Basins serve a common purpose of precision planting systems that support many other good agricultural management practices, such as timely planting or precision application of manure and fertilizers and better rainwater capture. The basins promoted are of various dimensions in different countries. The largest sizes are in Zambia (40 cm × 15 cm × 18 cm) where farmers aim at digging through hard pans, followed by those practiced in Lesotho (15 cm × 30 cm × 20 cm), with the smallest sizes in Zimbabwe (15 cm × 15 cm × 15 cm).

The third system is based on mechanical jab-planters originally developed by Brazilian manufacturers such as Fitarelli Machinas. The jab-planter has two compartments: one for fertilizer and one for seed and both are mounted on a wooden frame with two tips. Once the tips are pushed into the soil and opened by the operator seed and fertilizer drop into the planting hole. Although a jab-planter can seed in soils with crop residue retained as surface mulch, it has disadvantages such as clogging of the tips in sticky soil.

CA systems have been adopted by farmers in the USA, Latin America and Australia, mainly on large-scale commercial farms. For small-scale farmers in sub-Saharan Africa this cropping system is still new and areas under CA are small. Important documented benefits of CA, among others, include greater rainfall infiltration resulting in increased rainfall use efficiency[21], early planting[18], reduced soil erosion[19], increased soil biological activity[14] and reduced labor hours per unit yield and hectare[3,17,22].

Figure 2. Map of central and southern Malawi showing study sites.

CA-oriented technologies were introduced in Malawi by Sasakawa Global 2000 (SG2000) in 1998, which was supported by the Malawian Government through a targeted input program (TIP) funded by various donor organizations[3]. The major driver in this initiative was a set of management practices, which included denser plant population, specific herbicides for weed control and fertilization guidelines that were closely associated with the new governmental emphasis on input support. A direct consequence of the shift toward higher input agriculture and increased plant population densities was the increase in maize grain yield[3]. However, these past efforts concentrated on no-till and residue retention only, without any consideration for the part played by crop rotation or intercrop association.

The interest by the international research community, donors, non-governmental organizations (NGOs) and local governments in promoting CA as a widespread recommendation for small-scale farmers in sub-Saharan Africa has been contested by various authors[19,23]. These authors suggest that there is not enough scientific evidence about the putative benefits of CA to warrant large investment in widespread promotion of this new cropping system, and that CA would only fit into certain 'niches' under very specific circumstances[19]. Scientific evidence that supports the positive effects of CA compared with traditional tillage systems is based on the results of controlled experiments conducted on research stations that fail to represent smallholder production contexts and constraints[24]. This study therefore examines the effects of CA practices on crop productivity, profitability and soil quality under the conditions encountered by smallholder farmers in Malawi.

Materials and Methods

Description of experimental sites

This study was conducted over 6 years (2005–2011) in two communities of Lemu and Zidyana sections in the Bazale and Zidyana Extension Planning Areas (EPA), respectively. Lemu is located in Balaka district in the Machinga Agricultural Development Division (14, 79°S, 35, 01°E, 720 m above sea level) (Fig. 2). Zidyana is located in Nkhotakota district in the Salima Agricultural Development Division (13, 23°S, 34, 24°E, 532 m above sea level). Both communities are characterized by a unimodal rainfall pattern with a rainy season from November to April, and mean annual rainfall of 935 and 1375 mm for Lemu and Zidyana, respectively. The

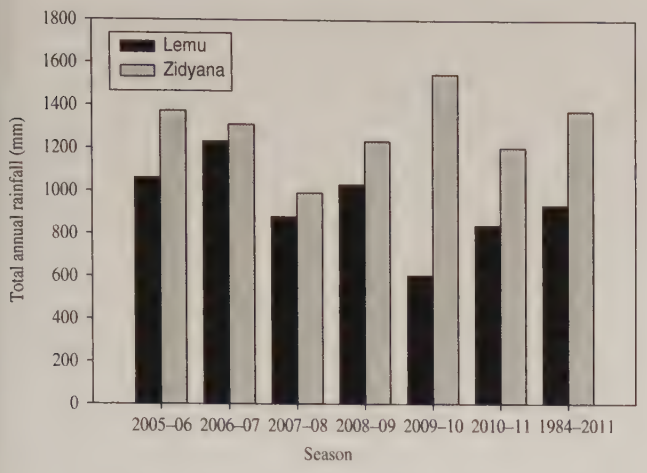

Figure 3. Total annual rainfall (mm) recorded in different cropping seasons at a central point of validation trials in Lemu and Zidyana, Balaka and Nkhotakota district, respectively, 2006–11.

long-term average minimum and maximum temperatures during the growing season are 27 and 28°C for Lemu and Zidyana, respectively.

The dominant soil types found in both communities are Luvisols with sandy clay loam soils and sandy loam soils in Lemu and Zidyana, respectively, in the top 30 cm layer[25]. Mean annual rainfall (mm) was higher in Zidyana as compared with Lemu during the study period (Fig. 3). Lemu received 330 and 94 mm less rainfall in the 2009/2010 and 2010/11 seasons, respectively, than the long-term average (935 mm). Zidyana received 385 and 172 mm less rainfall in 2007/08 and 2010/11 seasons, respectively, than the long-term average (1375 mm) during the research period.

Experimental design

The study was conducted on farmers' fields with a total of six farmers in each community hosting replicates of a validation trial spread across each target community. The main crop studied in both communities was maize (*Zea mays* L.) planted as a monocrop and intercropped with a legume in one treatment only. We report the results from 2005 to 2011 for maize in all years and legumes in some years when legumes were harvested.

Each farmer replicate was 3000 m^2 in size, which was sub-divided into three treatments that were randomly allocated to plots, each covering an area of 1000 m^2 as follows:

1. Conventional control plot consisting of traditional ridge and furrow land preparation planted with continuous monocrop maize (CPM). The residues were managed using methods commonly practiced in each EPA; i.e., the residues were incorporated into the ridges in Lemu and removed in Zidyana. Continuous monocrop maize was planted on the ridges.
2. CA plot with continuous monocrop maize (CAM) planted into the previous years' ridges (where they still existed) or directly into the plot without previous ridge formation. Crop residues from the previous years' harvests were retained as surface mulch. Maize seeds were planted as sole crops in no-till methods using a pointed stick (dibble stick).
3. CA plot with maize intercropped with a legume [cowpea (*Vigna unguiculata* L.) in Zidyana or pigeonpea (*Cajanus cajan* L.) in Lemu] (CAML). Both crops were planted with the dibble stick into the previous years' ridges (where they still existed) or directly into the plot without further ridging. Crop residues were retained as surface mulch as in treatment 2.

Trial management

All of the trials were managed by farmers with support from extension officers and overseen by researchers in both target communities. Field staff and technicians provided plot management recommendations. Hybrid maize DKC8033 was used for the duration of the trials. The cowpea variety Sudan was grown in Zidyana and the pigeonpea variety ICEAP0040 in Lemu. All of the plots were seeded after the first effective rains (e.g., rainfall greater than 30 mm after November 15th). Ridges in the conventional tillage practice (CP) were prepared by hand hoes around October in each year and crops were planted with hand hoes. Both legumes and maize were seeded at the same time. Ridge spacing was kept constant in the CA treatments: 75 cm between maize rows, 25 cm between planting stations and one living plant per station. The CPM plots followed normal spacing, planting pattern and planting population practiced by the farmers. In most cases, farmers have adopted the same 75 × 25 cm plant spacing according to recommendations from Sasakawa Global 2000[3]. Intercropped legumes were seeded in between maize rows, planting two seeds spaced at 60 and 40 cm apart for pigeonpea and cowpea, respectively.

This study adopted a moderate fertilizer application of 69 kg N ha^{-1}, which is less than the recommended 92 kg N ha^{-1}. This lower fertilizer rate is used by most farmers who benefit from the farm input subsidy program implemented by the Malawi government because of recent government efforts to subsidize farm inputs to a significant proportion of farmers unable to acquire inputs on their own. This was supplied by applying 100 kg ha^{-1} of N:P:K (23:21:0 + 4S) at seeding and 100 kg ha^{-1} of urea (46% N) approximately 3 weeks after planting.

All of the CPM plots were manually weeded as necessary, whereas weeds in both CA treatments were controlled by spraying with herbicides followed by manual weeding later. In treatment 2, after the first rain, annual and perennial weeds were killed by 2.5 liter ha^{-1} glyphosate [N-(phosphono-methyl)glycine], applied 7–10 days before planting using a knapsack sprayer under the guidance of the field officer. Then, 3 days after

planting, 6 liter ha^{-1} Bullet® [Monsanto; containing 25.4% Alachlor (2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl) acetamide) and 14.5% atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine)] was applied as pre-emergence herbicide, followed by manual weeding when the weeds were 10 cm tall or 10 cm in circumference. In treatment 3, only 2.5 liter ha^{-1} glyphosate was applied as a post-planting herbicide followed by manual weeding when the weeds were 10 cm tall or 10 cm in circumference. After three seasons, only 3 liter ha^{-1} of Bullet was necessary to control the broad-leaved weeds. It was the field officer's role to train the farmers to handle herbicides carefully and safely, and to spray uniformly. Training also included familiarization with different herbicides, knapsack sprayers, nozzle types and protective clothing (e.g., a raincoat, gum boots, rubber gloves and respiratory masks). Our aim was to use herbicides on farmers' fields in the safest possible way but only to use herbicides in the first few years, i.e., the transition phase between conventional and CA systems, and to discontinue the use of herbicides once the weed pressure had declined or diminished. This was necessary to avoid the extra labor burden on women[19].

Harvest measurements

At physiological maturity, maize was harvested from ten randomly selected samples of two rows 5 m long, collected from the middle of each treatment. The harvest area of the samples was used to extrapolate yields to an area basis. A sub-sample of 20 cobs per plot was dried and shelled to calculate grain yield at 12.5% moisture. All maize stalks and leaves without cobs were weighed at harvest; ten sub-samples per plot were air dried at least 4 weeks before the final dry weights were taken and biomass was calculated on an area basis. For cowpea and pigeonpea, sequential harvesting was carried out once the crop reached physiological maturity; by putting the pods from each plot into respective sequential harvest bags and leaving them to air dry. Net plots of ten samples per treatment each consisting of two rows 5 m long were used to calculate the final harvest yields extrapolated to an area basis. Legume biomass was measured by taking a sample of ten stems per plot, cutting them into pieces and collecting a sub-sample of between 500 and 1000 g. The sub-sample was weighed and air dried for at least 4 weeks before reweighing and was used to calculate biomass yield on an area basis. The rest of the biomass was returned to the field as surface mulch.

Net returns calculations

Net returns per hectare to each system were calculated using standard enterprise budgeting techniques to determine the production costs and profitability. A partial budget analysis was performed using labor data and prices of all applied inputs (seed, herbicides, fertilizers, etc.) from each of the plots during the entire period of the study. In order to improve the precision of the data, labor data (in person hours and minutes) were obtained from one on-farm trial per site for each operation (laying crop residue, tillage, herbicide application, planting, fertilizer application, weeding, harvesting, etc.). Labor data and prices for inputs were recorded for each treatment separately. Variable costs were recorded by extension workers working with farmers over the life of the project. Net return (profit) per hectare was estimated for each maize and legume yield (kg ha^{-1}) observation produced by each system based on average farm gate prices of US$ 0.21 and 0.71 (Lemu) and US$ 0.23 and 0.34 (Zidyana) for maize and legume, respectively, and the average variable costs for each treatment during the study period[26]. Maize prices were converted from Malawi Kwacha kg^{-1} to US$ kg^{-1} using official exchange for this time posted by the Reserve Bank of Malawi [http://www.rbm.mw/archive_dfbr.aspx (accessed October 17, 2011)]. This ensured comparability on a standard dollar ha^{-1} basis for different systems.

SOC and aggregate stability

SOC was determined using the method of Walkley and Black (cited by Van Reeuwijk[27]). This involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulfuric acid. Soil samples were collected from three depth layers, 0–10, 10–20 and 20–30 cm, in August 2011 from all treatments. A change in SOC as a result of CA was estimated by comparing soil samples from CA plots against CPM plots.

In order to convert percent SOC to g kg^{-1} soil, bulk density measurements were measured from three depth layers, 0–10, 10–20 and 20–30 cm, in August 2011. A composite sample was made from ten samples, each collected diagonally in the field from both furrows and ridges (where these still existed) or flat (where these ridges did not exist) under both CA systems, and ten samples from both ridges and furrows in conventional fields. At the time of sampling, the fresh residues were removed from the soil surface and the soil was air dried in the laboratory at Chitedze Research Station in Malawi. Disturbed soil samples were taken using a cylindrical sampling ring of known volume. The samples were oven dried at 105°C for 48 h in the laboratory. Bulk density was calculated as the mass of oven dried soil divided by total volume of soil. Surface soil samples were also taken from the same treatments in April 2011 from 0 to 30 cm depth; 50 g of a soil sub-sample was placed on a 2-mm sieve and soaked for 10 min in water in the laboratory. After soaking, the samples were agitated in water for 10 min at 48 strokes min^{-1} with strokes of 35 mm. Aggregates that remained on the sieve were dried at 105°C and weighed; and the percentages of water-stable aggregates were calculated.

Below-ground fauna

Three soil monoliths of 25 cm × 25 cm × 30 cm depth were taken from each reported treatment in April 2011. The samples were divided into three depth layers, 0–10, 10–20 and 20–30 cm, and hand sorted for macro-fauna (termites, earthworms, centipedes and others) and the numbers were counted[28].

Time to pond and rainfall simulation measurements

In the 2010/2011 season, a simple infiltration measurement, called 'time to pond'[29] was carried out on each plot in both communities using a watering can and a metal ring of 50 cm diameter placed on the soil surface. The ring was irrigated at the center with a predetermined volume of water at a constant rate. Time to pond was calculated as the moment when water started to flow out of the ring. Infiltration measurements were carried out at all sites in the third season when the maize was at the grain-filling stage. These were replicated on five different sites on each treatment, mainly in the inter-row space; when the soil was at, or close to, field capacity. Twelve rainfall simulation measurements were carried out at each of the two communities simultaneously with time-to-pond measurements. The aim of this exercise was to calibrate time to pond with infiltration for a specific soil type of the two communities. Measurements of infiltration were carried out with a small rainfall simulator as described by Amézquita et al. (cited by Thierfelder and co-workers[14,21,30]). Horton's infiltration model (Eq 1) was used to fit the data and to describe the exponential decay of the infiltration rate during the experiment.

$$f_{cap} = (f_0 - f_c)\, e^{-bt} + f_c \qquad (1)$$

where f_{cap} is the maximum infiltration capacity of the soil (mm h^{-1}), f_0 the initial infiltration capacity (mm h^{-1}), f_c the final infiltration capacity (mm h^{-1}), b is Horton's constant and t the elapsed time (h).

Final infiltration rates were plotted against time to pond and a linear model fitted to the data to obtain their relationship. This linear relationship was used to estimate total infiltration (mm) specific for the soil type in each community (Fig. 4).

Statistical analysis

A linear mixed effects model (Restricted Maximum Likelihood) procedure[31] was used to analyse data on yield, gross benefits, net returns, SOC, water infiltration, soil fauna, aggregate stability and bulk density from the on-farm trials. The farmers were considered to be random effects because the farmers were randomly selected from a wider population of farmers in each community to host non-replicated on-farm trials. The analysis of the mentioned soil quality and yield data was performed separately for Lemu and Zidyana communities because

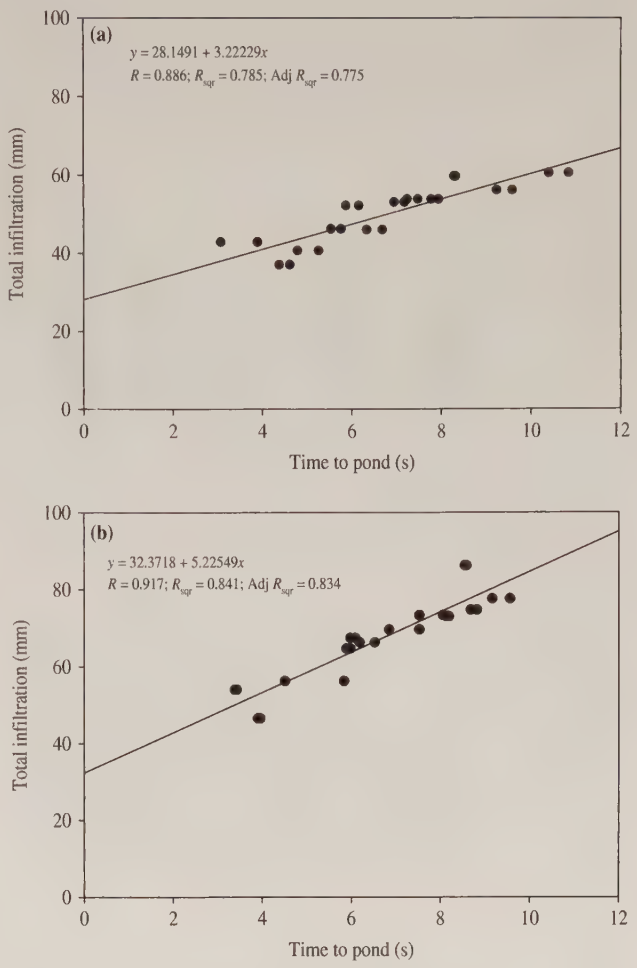
(a)
y = 28.1491 + 3.22229x
R = 0.886; R_sqr = 0.785; Adj R_sqr = 0.775
Total infiltration (mm)
Time to pond (s)
(b)
y = 32.3718 + 5.22549x
R = 0.917; R_sqr = 0.841; Adj R_sqr = 0.834
Total infiltration (mm)
Time to pond (s)

Figure 4. Total infiltration (mm) against time to pond (s) at Lemu (a) and Zidyana (b) in Balaka and Nkhotakota districts, respectively, Malawi, 2011.

the communities may not be the representatives of all possible communities in the study areas. Where significance was detected, the means were compared using the standard error of the difference (SED). Statistical analyses were performed using GenStat version 13[32]. Yield and soil quality data were tested for normality and homogeneity and showed normal population distribution and homogeneity of variance.

Results

Maize and legume grain and total biomass yield

On-farm evaluation of CA systems and conventional tillage practices (CPM) exhibited differing trends in maize yield among treatments across seasons at the two sites (Figs. 5a and 5b). In Lemu, the drier of the two sites, significant differences in maize grain yields were observed from the first cropping season onwards, with both CA systems being superior to CPM. Over the study period, the highest increase in maize yields between CA and CPM

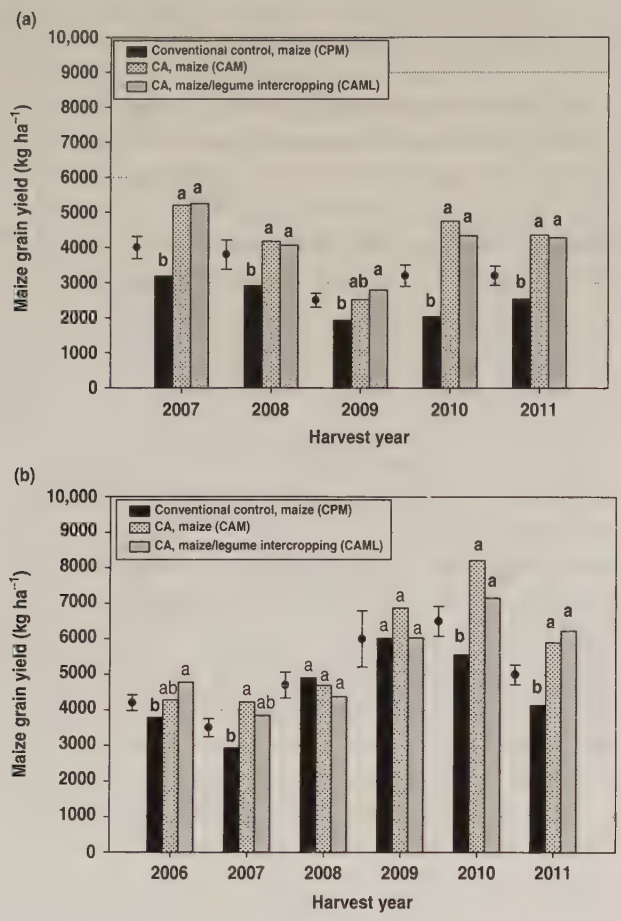

Figure 5. (a) Maize grain yields in conventional tilled, continuous maize, CA continuous sole maize and CA maize–legume intercrop located on farms in Lemu, Bazale EPA, Balaka district, southern Malawi. Error bars indicate standard error of the difference (SED). (b) Maize grain yields in conventional tilled, continuous maize, CA continuous sole maize and CA maize–legume intercrop located on farms in Zidyana EPA, Nkhotakota district, central Malawi. Error bars indicate standard error of the difference (SED).

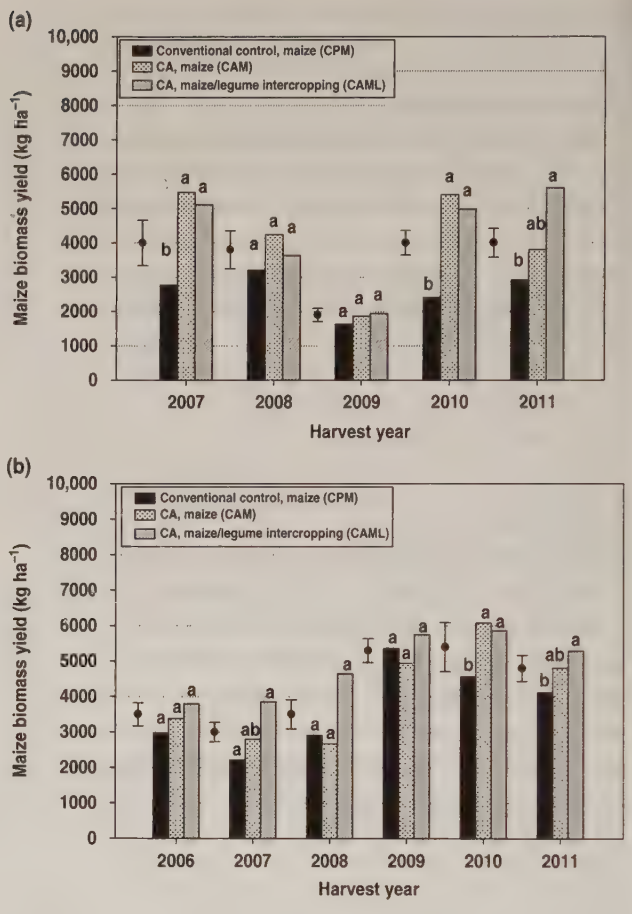

Figure 6. (a) Total biomass yields in conventional tilled, continuous maize, CA continuous sole maize and CA maize–legume intercrop located on farms in Lemu, Bazale EPA, Balaka district, southern Malawi. Error bars indicate standard error of the difference (SED). (b) Total biomass yields in conventional tilled, continuous maize, CA continuous sole maize and CA maize–legume intercrop located on farms in Zidyana EPA, Nkhotakota district, central Malawi. Error bars indicate standard error of the difference (SED).

was observed in 2009/10 season with 2.7 and 2.3 Mg ha^{-1}, translating to 133 and 113% more yield in CAM and CAML, respectively, than CPM. The lowest increase in maize yields was observed in the 2008/09 season, with 0.6 and 0.9 Mg ha^{-1}, translating to 30 and 44% more yield in CAM and CAML, respectively, than CPM.

There were no significant differences in maize yield in Zidyana during the first four cropping seasons. In the fifth season, maize yields were 48 and 29% higher in CAM and CAML, respectively, than CPM and in the sixth season CAM and CAML had 43 and 51% higher maize grain yields, respectively, than CPM.

Total biomass production was significantly different between CPM and the two CA systems during 2006/07, 2009/10 and 2010/11 in both Lemu and Zidyana (Figs. 6a and 6b). The highest total biomass production during these cropping seasons was observed in the driest season of the study period of 2009/10 in Lemu, where CAM and CAML gave about 125 and 108%, respectively, over CPM. In Lemu during 2010/11 when legume biomass was recorded, total biomass production from CAML gave about 47% more biomass over CAM. In Zidyana, CAM and CAML gave 33 and 28% more total biomass yield in 2009/10 and 2010/11, respectively, than CPM. Legume grain yield across seasons was significantly different in Lemu only (Table 1). Although data were only recorded during two out of five seasons, pigeonpea yield was significantly higher during 2009/10 (0.6 Mg ha^{-1}) compared with 2010/11 (0.5 Mg ha^{-1}).

Net return analysis

Since the two communities differed in terms of input cost and farm gate prices of maize and legume grain though

Table 1. Pigeonpea and cowpea grain yield ($kg\,ha^{-1}$) in Lemu and Zidyana communities in CA maize intercropped with grain legume, 2006–2011, Malawi.

Season	Lemu	Zidyana
2006	N/A	283.6a
2007	N/A	274a
2008	N/A	530a
2009	N/A	110a
2010	559.5a	135a
2011	489.8b	226.7a
Standard errors	142	67.26
P-value	0.043	0.487
Wald statistic	4.09	4.45

Values followed by the same letter in each column belonging to the same site are not significantly different from each other at $P<0.05$.
N/A means that data were not available from farmers during that particular cropping season.

they had similar labor costs, separate profitability analyses for both sites are presented (Table 2). Farmers spent at most $50\,days\,ha^{-1}$ (US$128) producing maize under CA systems compared with $62\,days\,ha^{-1}$ (US$160) spent under CP. However, the average variable costs were higher in CA systems compared with the conventional tillage due to additional costs for herbicide for weed control. Average input costs were US$239, 341 and 354 for the conventional practices, CA sole maize and CA maize–pigeonpea intercrop, respectively, in Lemu and US$222, 324 and 346 for the conventional practice, CA sole maize and CA maize–cowpea intercrop, respectively, in Zidyana. Nevertheless, average gross benefits were 67 and 85% higher in Lemu and 42 and 51% higher in Zidyana in CA sole maize and CA maize–legume intercrop, respectively, than conventionally tilled maize. In Lemu, both CA systems resulted in more than three times higher net returns compared with conventional tillage systems. In Zidyana, CA systems resulted in 32 and 23% higher gross margins with CA monocrop maize and CA maize–legume intercrop, respectively, than conventionally tilled maize. While significant differences in maize grain yields between conventional tillage and both CA systems were observed from the first season of experimentation in Lemu, net returns were significantly higher in the fourth and fifth seasons (Table 3). Net returns were 1222 and 1383% higher in CA sole maize and CA maize–pigeonpea intercrop than conventional tillage in 2010, and 222 and 424% higher in CA sole maize and CA maize–legume intercrop than in conventional tillage in 2011. In Zidyana net returns were correlated with maize grain yield, with significant difference between the two CA systems and conventional tillage observed in the fifth and sixth seasons. Net returns were 63 and 35% higher in CA sole maize and CA maize–pigeonpea intercrop than conventional tillage in 2010, and 61 and 65% higher in CA sole maize and CA maize–legume intercrop than in conventional tillage in 2011. Both CA systems resulted in a more than doubled return to labor compared with CP in Lemu. In Zidyana, the CA monocrop maize and CA maize–legume intercrop systems resulted in 81 and 41%, respectively, higher returns to labor than CPM.

Total organic carbon

Soil organic carbon ($g\,kg^{-1}$ soil) measured at 0–10, 10–20, 20–30 and 0–20 cm was not significantly different between CA and CPs ($P\leq0.05$) (Table 4). Although soil samples were collected from both furrows and the previous years' ridges (where these still existed) in CA plots, these were merged in the analysis because we did not observe any significant differences between them.

Below-ground fauna

Differences between treatments in the faunal groups of earthworm and termites were only observed in Zidyana (Table 5). At Lemu, spatial variability of these faunal groups was too large to detect any significant difference between treatments. In Zidyana, the earthworm population was highest ($48\,earthworms\,m^{-2}$) in CAM, followed by CAML ($40\,earthworms\,m^{-2}$) and lowest ($9\,earthworms\,m^{-2}$) in CPM treatment. At both sites centipede populations were higher in the top 30 cm of soil of CAM than CPM, whereas the rest of the faunal populations did not show significant difference between treatments.

Infiltration and aggregate stability

Calibrated infiltration rates from time to pond values measured in April 2011 showed significant differences between treatments at both study sites (Table 6). In Lemu, the highest total infiltration was recorded in CAML (54 mm) and CAM (51 mm) as compared with the CPM treatment (43 mm). This represents about 18 and 24% more infiltrated water on CAM and CAML, respectively, than in the CPM treatment. In Zidyana, total infiltration was higher in CAML (75 mm) and CAM (74 mm) than in CPM treatment (52 mm). About 41 and 42% more water entered into the soil profile in CAM and CAML treatment, respectively, than CPM. There were no significant differences in percent of water-stable aggregates between CPM and both CA systems at both sites for all classes (Table 6).

Discussion

Maize grain and total biomass production

Substantial maize yield increases were obtained by moving away from the ridge and furrow system that involved incorporation or removal of crop residue as compared with CA systems that retained all *in-situ* produced crop residue as surface mulch. Despite production

Table 2. Farm Enterprise Budget Analysis for CA and CPs 2005–2011.

	Lemu			Zidyana		
	CP	**CA**	**CAL**	**CP**	**CA**	**CAL**
Gross receipts	528.6	881.5	979.7	1047.2	1309.5	1293.7
Variable costs						
Inputs	238.5	341.0	353.6	221.7	323.7	346.1
Labor days (6 h days)	61.7	39.9	49.4	61.7	39.9	49.4
Labor costs	159.5	103.2	127.9	155.6	100.7	124.7
Sprayer costs		1.7	1.2		1.7	1.2
Total variable costs	398.1	445.9	482.8	377.3	426.1	472.1
Net returns (US$ ha^{-1})	**130.5**	**435.5**	**497.1**	**669.9**	**883.3**	**821.9**
Returns to labor (US$ per day)	1.8	5.2	4.9	5.4	9.8	7.6

Note: CP, conventional practice; CA, conservation agriculture sole maize; CAL, conservation agriculture maize–legume intercrop. Labor data (in person hours and minutes) was obtained from one on-farm trial per site for each operation (laying crop residues, tillage, herbicide application, planting, fertilizer application, weeding, harvesting, etc.).
Price data were based on all applied inputs (seed, herbicides, fertilizers, etc.) from each of the plots during the entire period of the study.

Table 3. Summary of gross benefits and net returns for each year in Lemu and Zidyana communities for CA and CPs 2005–2011.

Season	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Mean**	**SD**
			------Total gross benefits (US$ ha^{-1})------					
Lemu								
CPM	N/A	666.0b	607.7b	406.4a	428.3b	534.4c	528.6	111.9
CAM	N/A	1090.0a	873.1a	528.8a	1000.1a	915.3b	881.5	213.9
CAML	N/A	1098.0a	851.0a	586.6a	1112.8a	1250.1a	979.7	262.6
SED	N/A	103						
Zidyana								
CPM	869.0a	672.0a	1129.0a	1382.0a	1278.0b	953.0b	1047.2	265.9
CAM	981.0a	972.0a	1080.0a	1579.0a	1887.0a	1358.0a	1309.5	336.1
CAML	1155.0a	957.0a	1126.0a	1407.0a	1676.0a	1441.0a	1293.7	305.3
SED	151							
			------Net returns (US$ ha^{-1})------					
Lemu								
CPM	N/A	352.9b	100.4a	−0.2a	43.1b	156.3c	130.5	137.6
CAM	N/A	728.7a	306.5a	69.6a	569.8a	503.0b	435.5	254.5
CAML	N/A	684.4a	252.3a	90.0a	639.3a	819.7a	497.1	310.3
SED	N/A	130						
Zidyana								
CPM	562.9a	359.5a	622.2a	975.3a	892.7b	606.7b	669.9	226.7
CAM	624.3a	610.2a	512.7a	1120.3a	1457.0a	975.0a	883.3	366.8
CAML	746.7a	542.8a	527.7a	910.5a	1202.8a	1000.8a	821.9	266.5
SED	151							

Values followed by same letter within each column at the same site are not significantly different from each other at $P < 0.05$.
SD, standard deviation.

and retention of adequate levels of crop residue as surface mulch (which were assumed to be of poor quality in the monocrop CA maize system), CA did not have an adverse effect on crop yield for both soil types and rainfall regimes during the study period—attenuating concern that N immobilization may lead to lower crop yield, as suggested by other authors[19]. Since all of the plots received the same amount of fertilizer and maize varieties, we can surmise that differences between treatments are due to a combination of differences in tillage and land preparation methods, residue management, cropping systems and weed control strategies.

Greater nutrient and water use efficiency in CA systems than CPs could be assumed to have contributed to greater yields. In the drier environment of Lemu (characterized by sandy clay loam soils), most of the yield increase was observed in the driest year of 2009–10 (Fig. 5a) with 2.7 and 2.3 Mg ha^{-1} more maize obtained in the monocrop

Table 4. Soil organic carbon ($g\,kg^{-1}$ soil) in validation trials on farmers' fields consisting of conventional tillage, CA continuous sole maize and CA maize intercropped with grain legume after more than five seasons in Lemu and Zidyana sections, Balaka and Nkhotakota districts, Malawi, 2011.

	Soil organic C					
	0–10 cm	10–20 cm	20–30 cm	0–10 cm	10–20 cm	20–30 cm
	Lemu			Zidyana		
Conventional tillage	14.26 ± 3.56a	12.96 ± 5.67a	12.26 ± 5.77a	9.11 ± 4.40a	6.40 ± 3.05a	5.47 ± 2.31a
CA sole maize	15.41 ± 5.29a	15.81 ± 6.36a	13.26 ± 5.48a	8.61 ± 4.37a	6.71 ± 3.82a	5.75 ± 2.92a
CA maize–legume	13.26 ± 4.31a	13.51 ± 6.65a	12.38 ± 6.85a	10.62 ± 4.42a	7.49 ± 1.57a	6.12 ± 1.60a
Probability level	NS	NS	NS	NS	NS	NS

Values followed by the same letter in each column are not significantly different from each other at $P < 0.05$.

Table 5. Below-ground fauna counts (m^{-2}) from 0 to 30 cm depth in validation trials on farmers' fields consisting of conventional tillage, CA continuous sole maize and CA maize intercropped with grain legume over five seasons in Lemu and Zidyana sections, Balaka and Nkhotakota districts, Malawi, 2011.

	Lemu				Zidyana			
Treatments	Termites	Earthworms	Centipedes	Others*	Termites	Earthworms	Centipedes	Others[1]
Conventional practice	47a	2a	4b	16a	46b	9b	6b	18a
CA sole maize	396a	41a	20a	37a	123ab	48a	18a	33a
CA maize/legume	403a	42a	12ab	92a	415a	40a	13ab	31a
Probability level (PF)	5%	5%	5%	5%	5%	5%	5%	5%

Values followed by same letter within each column are not significantly different from each other at $P < 0.05$.
[1] Others included white grubs, millipedes, red ants, etc.

CA maize system and the CA maize–legume intercrop system, respectively, than CP. The substantial increase in maize yield in CA in Lemu from the first season could be attributed to a combination of minimum tillage and retention of crop surface residue as mulch. Mulch cover improved water infiltration even after the first season, especially under drier or moisture-limited conditions, thereby improving the effect on soil water balance in CA compared with CPs[17,33,34]. In this study, we showed that it was possible to produce and retain 2–5.5 $Mg\,ha^{-1}$ of crop residues as surface mulch (Figs. 6a and 6b), thus providing a significant contribution to total biomass over conventional tillage systems, particularly in the last two seasons of the study period. Although we did not measure the amount of biomass remaining as surface mulch at the end of the winter season, the visual appraisal by the field staff suggested that a large portion of the residues could be retained as surface mulch despite an abundance of termites and prevailing warm and moist conditions in both study areas. Crop residue retained as surface mulch in the range of 4–6 $Mg\,ha^{-1}$ has been suggested to alter rainwater infiltration[34]. In the wetter environment of Zidyana, characterized by sandy loam soils, significant differences in maize yield between CA and CP were only apparent after 4 years of experimentation. The results of this study suggest that in marginal environments, such as that of Lemu, benefits from CA are realized earlier compared with environments with optimal conditions for crop production, such as Zidyana.

A time lag between investment in CA and tangible benefits has been reported[35]. Such information is important for farmers because they expect tangible benefits in a relatively short time period when changing to new agriculture systems[19]. Some studies have reported difficulty in retaining crop residues as surface mulch, largely due to competition with livestock, particularly during the dry season when communal grazing is common[20,36]. In most parts of Malawi, very few farmers own livestock. Therefore, the potential seems higher for significant adoption of crop residue retention as surface mulch in CA in most areas of Malawi. In some areas, crop residues are traditionally burned to clear fields of residue and to facilitate the hunting of rodents (a significant source of protein and income). Competing use of maize stover include use as a fuel source for fire-sterilizing tobacco nursery beds against soilborne diseases; a cooking fuel source, as trees are scarce in the context of deforestation; and for fencing gardens. Farmers in some areas expressed concern about spreading crop residues in cases where termites or white grubs are common. Thus, community use of crop residue may be an important impediment to continued adoption of CA.

Maize and legume intercropping

Neither legume crop appeared to compete with the maize crop, as there was no significant difference in maize yields between CA sole maize and CA maize–legume intercrop

Table 6. Soil aggregate stability (%) and infiltration (mm) in validation trials on farmers' fields consisting of conventional tillage, CA continuous sole maize and CA maize intercropped with grain legume over five seasons in Lemu and Zidyana sections, Balaka and Nkhotakota districts, Malawi, 2011.

	Aggregate stability (%)					
Treatment	**Class**					
Lemu	0.5	1	2	4.75	10	Infiltration (mm)
Conventional practice	64.4(10.9)	40.5(11.9)	40.52(25.6)	6.8(4.9)	9.4(12.2)	43.1b
CA sole maize	65.9(11.3)	49.0(22.4)	37.8(18.4)	4.2(2.8)	5.5(5.0)	50.8a
CA maize/legume	58.5(5.9)	53.3(16.8)	41.2(18.5)	4.5(3.4)	12.1(12.1)	53.6a
Probability level (PF)	NS	NS	NS	NS	NS	5%
Zidyana	0.5	1	2	4.75	10	Infiltration (mm)
Conventional practice	63.42(19.1)	49.1(13.3)	43.1(15.8)	10.3(11.7)	9.0(15.0)	52.3b
CA sole maize	68.72(10.1)	51.8(16.7)	38.0(15.5)	18.2(11.2)	4.6(10.1)	73.9a
CA maize/legume	64.53(12.0)	50.2(10.1)	32.1(29.6)	8.4(5.6)	2.6(6.4)	74.5a
Probability level (PF)	NS	NS	NS	NS	NS	5%

Values followed by the same letter in each column for infiltration are not significantly different from each other at $P<0.05$. Values in parentheses indicate standard deviations.

(Figs. 5a and 5b). Thus, the selected legume crops may be considered a 'bonus' in CA systems, although weed control can be more challenging with this system. Other studies have demonstrated a significant contribution to biomass production by intercropping maize with cereals compared with monocrop cereals[17,24,37]. Although farmers planted the type of legumes adapted to their local context, the grain yields obtained were lower than the potential. ICEAP00040 pigeonpea[38] and Sudan 1 cowpea[39] cultivars have a yield potential of 1.6 and 1.8 Mg ha^{-1}, respectively, when grown on farm, whereas the range in this study was 0.5–0.6 Mg ha^{-1} for pigeonpea in Lemu and 0.1–0.5 Mg ha^{-1} for cowpea in Zidyana. This difference (between potential yield and actual yield obtained in this study) was probably due to an inadequate number of sprays against insect pests such as aphids (*Aphis gossypii*) and elegant grasshoppers (*Dichromorpha elegans*) as well as dry spells causing flower abortion.

There was also a large variability in terms of legume management by farmers. In Lemu, pigeonpea was harvested in some cases earlier than the harvest data could be captured. Therefore, productivity gains in terms of pigeonpea yield and total biomass in CAML was underestimated for those seasons when pigeonpea data were missing.

Of the two legumes, pigeonpea grain has a high demand in Malawi and India (an export market from Malawi), and the stems are used as fuelwood[40,41]. Although not measured in this study, there are additional benefits of intercropping maize with legumes. Pigeonpea intercropped with maize can add up to 60 kg N ha^{-1} through nitrogen fixation without additional labor requirements[40]. Pigeonpea, with its deep taproots, may assist in breaking the widespread hoe pans prevalent in most smallholder farmers' fields in Malawi, thus improving soil structure and porosity. These changes created by roots could allow more water to infiltrate the soil instead of ponding on the soil surface. The mixing of maize residue that is of low quality, and higher quality residues from legumes, could potentially reduce the C:N ratio by increasing the nitrogen component in the relation, thus avoiding temporary N immobilization by micro-organisms[42,43].

A critical CA component in Malawi will be the 'rotation' principle. The land holdings of typical farmers are too small to dedicate land to serial rotational cropping systems, and intercropping might be the only reasonable alternative to venture into diversification. The ability of suitable intercrops such as cowpea or pigeonpea to reduce pests and diseases has not been adequately investigated or sufficiently understood[14]. Farmers are also hesitant to grow more legumes if there are no readily available markets for the sale of produce[14,40,44].

Profitability analysis

Both CA systems resulted in higher net returns compared with CPs from the fourth season in Lemu and from the fifth season in Zidyana. Although farmers did not achieve substantial profit in CA systems during the initial years of the experiment, CA offers some socio-economic benefits even with similar net returns in the two systems. Producing maize using CA required fewer labor days than CPs. Labor savings of 35 and 20% were achieved in the monocrop CA maize system and CA maize–legume intercrop systems, respectively. The higher labor requirement for CP is primarily due to land preparation and weed control. Our discussion with farmers revealed that farmers used the saved labor to grow other crops, such as groundnuts, paprika, cotton, rice and horticultural crops, as well as to allow women more time to participate in local markets.

Under CA, producers are expected to save between 9 and 19 days in land preparation and weeding, respectively. A similar analysis of no-till cropping involving planting basins in Zimbabwe reported more labor days to produce maize under CA compared with CPs[45]. Planting basin CA is perceived as a more labor intensive form of CA than the dibble-stick technique used in this study. Nevertheless, higher total variable costs were realized in the CA systems compared with the conventional practice (at most US$483 in CA versus US$398 in CP in Lemu and at most US$883 in CA versus US$670 in CP in Zidyana). This is mainly due to higher input costs for different herbicides and sprayers used in those treatments. The additional costs that need to be considered when introducing CA systems are the investment for herbicides, knapsack sprayers and protective gear. However, farmers can cooperatively buy and share the latter to reduce costs. Although it can be argued that production costs can be offset by higher gross margins realized under CA systems, incurring additional capital costs could be a disincentive for adoption of CA for the majority of smallholder farmers in Sub-Saharan Africa and, in particular, Malawi[46,47].

In Lemu both CA systems resulted in more than three times higher gross margins compared with conventional tillage systems. In Zidyana, CA systems resulted in 32 and 23% higher gross margins with CA monocrop maize and CA maize–legume intercrop, respectively, than conventionally tilled maize. The cost of producing 1 kg of maize is lower with CA systems, earning more than double the return to labor than with the conventional farmer practices (Table 2). Higher gross margins, the lower cost of producing 1 kg of maize, and higher returns to labor have been reported under conservation farming in Zimbabwe[45]. The prime driver of CA adoption by smallholder farmers in other regions is profitability and the reduction of risk[22].

Soil quality

On-farm validation trials showed that CA systems led to an increase in abundance of soil fauna and infiltration compared with CPs. The retention of a large quantity of crop residue produced *in-situ* in combination with minimum tillage was sufficient to increase water infiltration and thereby reduce runoff and stimulate macro-fauna activity[14,19,48,49]. The increase in the macro-fauna has been previously reported to create a large number of channels that aid in water infiltration[50]. Higher soil organic carbon and aggregate stability have been reported in CA systems with crop residue retained as surface mulch than conventional tilled systems with residue incorporated in long-term experiments in Mexico[51,52]. However, this was not the case in our study. We suspect soil sampling at different depths led to insignificant differences in soil C between CA and CPM fields. In Malawi ridges in CPM plots are often 30 cm deep and since the CA fields become flat after years of no ridge making, there might be differences in the depths sampled. We therefore propose improvements in soil sampling procedures when a comparison is made between soil samples taken from the ridges and from the flat.

Conclusion

On-farm validation trials in central and southern Malawi found that CA systems increased maize yield, net return and soil quality compared with CPs. Application of the three principles of CA, i.e., minimum tillage, retention of crop residue as surface mulch and crop association appeared to be vital for these benefits. In the drier environment of Lemu, CA yielded positive benefits on maize yield from the first season onwards, while it took longer in the wetter environment of Zidyana EPA. Differences in maize grain yield in Zidyana were only apparent after 4 years of experimentation. Labor savings of 35% were achieved in CA sole maize and 20% in the CA maize–legume intercropping system as compared with the conventional control, coupled with increased yields which make CA more profitable. Higher variable costs (for herbicides and spraying) can be offset by the farmers through higher net returns realized under CA. Nevertheless, for a majority of the smallholder farmers in Malawi the additional capital costs for inputs can be a disincentive for CA adoption. Therefore, farmers will require support from NGOs, the public and the private sector to offset higher incremental costs of adoption of CA. CA increased water infiltration and below-ground fauna (e.g., earthworms and termites) in the locations analyzed. Lack of an absolute increase in soil organic carbon content points to a gradual increase in soil fertility under the different CA systems because surface-placed crop residues are less exposed to microbial attack. The study finds that associating maize with grain legumes appears to be a more viable option of CA than crop rotation for farmers with limited land-holding sizes and food security concerns. However, the effect of different intercrops on eliminating pest and disease cycles is poorly understood and needs further research. Although our results showed a potential increase in productivity in CA than CPs using a standard package, there is a need to link these to farmer resource endowment and differing biophysical conditions. Nonetheless, CA appears to be a promising system for small-scale farmers to sustainably increase food production in Malawi.

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Esthetic and spiritual values motivating collective action for the conservation of cultural landscape—A case study of rice terraces in Japan

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Abstract

Japan's rice terrace landscapes are not only used for food production but also appreciated as a place of high biocultural value. This paper pursues the question as to how far esthetic and spiritual values influence the motivation to participate in collective agricultural actions aiming at the conservation of traditional land use systems, the respective cultural (= traditional rural) landscapes and their biocultural diversity. Our results show that in the Ownership System of Ōyamasenmaida (Chiba Prefecture, Japan) landscape beauty is the main motivator for the mainly urban volunteers (the 'tenants') to participate in activities of the local Preservation Association, as well as for visitors who merely come to enjoy the scenery of the rice terraces. The active tenants, however, differ from the 'passive' visitors in their ecological interest and emotional attachment to the area. Interestingly, there is also a difference regarding the belief in nature spirits. A higher percentage of people who can imagine that such spirits are always present have been found among the tenants than among the visitors. Even more significant in this respect was the difference between female tenants and female visitors. To what extent spirituality is the cause for or an effect of involvement in nature conservation activities cannot be concluded from this survey. Future studies should therefore take a closer look at the connection between spirituality/religiosity and engagement in nature conservation activities. In Western countries (mainly in Central Europe or North America), nature conservation works on a more 'scientific' level, mobilizing engagement through scientific evidence on, for example, losses of species or biodiversity. Addressing the motivations of the volunteers on an emotional, esthetic or social level could be a promising way forward.

Key words: esthetics, biocultural diversity, collective action, conservation of traditional rural landscape, motivation, Ōyamasenmaida (Chiba Prefecture, Japan), rice terraces, *satoyama*, spirituality, *Tanada* Ownership System

Introduction

Aims of this article

Traditional land use systems and the respective cultural (= traditional rural) landscapes of high biocultural diversity are under great pressure due to technological and socio-economic changes and in many parts of the world are not economically viable anymore. If the market fails, some kind of action is needed to preserve this biocultural diversity. Thus, mobilization and motivation of volunteers to participate in the management of traditional land use systems become important factors. During field research into the biodiversity of a rural paddy landscape in Central Japan (see subsection 'Study site') the first author became aware that hard scientific facts, such as the conservation of species, were not enough to motivate

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people to engage in such activities. Esthetic and spiritual values might be even stronger motivators. In this article, we compare a group of mainly urban volunteers who invest personal time, money and manual labor to contribute to the conservation of a terraced rice landscape in Japan with a group of visitors 'passively' admiring the same terraced landscape. Both groups might appreciate the beauty of the landscape; however, those actively contributing to conservation and agricultural management might be driven by additional motivations. Knowledge about the factors triggering readiness to participate actively in activities can be helpful in developing effective conservation strategies.

Satoyama *and biocultural diversity*

As in many parts of the world, most of the Japanese landscape has been shaped by man. In the hilly and mountainous regions, which cover more than 70% of the total land area[1], small-scale agriculture, adapted to the topographic situation, formed the 1000-year-old cultural '*satoyama*' landscape[2,3], consisting of villages at the foot of the mountains, paddies and other arable crop fields mainly on terraces, secondary grasslands, and coppiced forests on the slopes, conifer plantations, bamboo groves, water reservoirs, ponds, streams, shrines, temples and graveyards. For the Japanese, *satoyama* is often the symbol of the last remnants of a natural environment[4]. The FAO has included *satoyama* sites in its list of Globally Important Agricultural Heritage Systems, which are defined as 'Remarkable land use systems and landscapes which are rich in globally significant biological diversity evolving from the co-adaptation of a community with its environment and its needs and aspirations for sustainable development'[5]. Paddy fields play a key role. In total 54% of Japan's farmlands are paddy fields[6]; of these, 14.9% are terraced rice fields ('*tanada*' in Japanese)[7]. Apart from food production and their relevance for other ecosystem services, e.g., prevention of floods and erosion, water purification or ground water protection[1,8], paddies are important biotopes for a rich and specialized fauna and flora. A recent study, presented at the 10th UN Convention of Biodiversity, lists 5668 animal and 2075 plant species that are connected to the rice field ecosystem in Japan[9]. Also, from a cultural and religious perspective, rice played and continues to play a prominent part in Japanese daily life[10–13]. Lately, an increased awareness can be found in Japanese society regarding rice terrace landscapes, also called '*senmaida*' (1000 rice fields), which are perceived by many people as the 'nature' most close to them[14], a place to which they feel a strong attachment. *Tanada* is the landscape of their ancestors, representing culture, tradition, (spiritual) homeland and national identity—all in all, a landscape loaded with emotions. Besides that, it is considered to be attractive due to its esthetic value[14].

Satoyama *and biocultural diversity at risk*

Currently, 40% of the land area is estimated in the Fourth National Biodiversity Strategy of Japan to be *satoyama*[2]. Its continued existence, however, is at a great risk, due to serious demographic and economic upheavals. Declining birth rates, an aging society (nearly one-quarter of the Japanese are 65 years or older[15]), small average farm size[16], high costs of farm labor[17], and thus high production costs[18] in combination with falling rice consumption[19], result in a decrease of agricultural income[1], and consequently in the migration of the younger population to the cities. This, in turn, leads to 'retirement farming' (70% of Japanese agriculture rests on the shoulders of retired people[20]) and finally to the abandonment of agriculture and farmland and to depopulation of the rural areas[1,21].

Rise of collective action

Initiatives for a revival of rural areas started in the late 1980s–early 1990s in the form of local citizens' movements as well as in government programs, and are increasing continuously[20,22–24]. Thus, the Ministry of Agriculture, Forestry and Fisheries of Japan registered joint projects between farmers and non-farmers involving 19,514 organizations nationwide operating over an area of 1.43 million ha, i.e. 31% of the Japanese cultivated land area[1,25]. Several activities introduced by the Japanese government are targeted specifically at the conservation of the *tanada* landscape, such as, the yearly *tanada* summit to strengthen the local economy[14,26], the nationwide award of the country's 100 most beautiful rice terraces[27] in order to increase their popularity and to bring citizens to engage in their protection[27], or the support of the legal implementation of the *Tanada* Ownership System[28]. The *Tanada* Ownership System is a land tenure system, where non-farmer volunteers ('the tenants'), often city dwellers, rent a piece of land (mostly rice terraces, but also other arable land) against a certain rental fee and cultivate it under the guidance of the landowners or other experienced supervisors (mainly locals)[14,19,28].

The link between esthetics and spirituality—the Japanese concept of nature

The esthetic appreciation of nature has a long tradition in Japan[29] and often also has a religious meaning[30,31]. This becomes evident in the Shintoistic deification of impressive natural phenomena in literature and poetry, in the visual arts or in the garden design of monasteries, where idealized and refined images of nature are reproduced in miniature format, sometimes reaching a maximum of abstraction and reduction and arranged in a scenic composition. In Japanese 'religious understanding'—resulting from mythology, the '"Buddha-nature" in all things'[32] and Shintoism with its proverbial myriad *kami-sama*—all creatures in nature have a soul, even natural

phenomena and inorganic objects (*kami-sama* are divine powers, which are inherent in all things that give the onlooker a feeling of awe, such as the sun, moon, rocks, rivers, old trees, caves, flowers, animals, and even people with an outstanding personality)[12,30,32]. Moreover, mythical creatures also animate nature. Man and nature are perceived as a union, inseparable from the spiritual world[30,32]. This could be one of the reasons why Japanese people do not make the same sharp distinction between 'man-made' and 'natural' as Westerners do[32–35]. This attitude, however, does not automatically imply that Japanese people have a more heedful and harmonious relationship with nature (which is a common stereotype), but merely indicates that they appreciate the formative human hand in nature. Japanese have a preference for semi-natural rural sceneries[36,37], while many Westerners long for untouched primary nature[29,31,35–42].

At this point it must be noted that Japanese religious understanding should not be viewed from a Western point of view. 'The word, religion, is historically and culturally constructed'[43]. A large percentage of Japanese people define themselves as 'unreligious', although they regularly conduct religious rituals, festivals or other religious events[43–46]. To the Japanese 'religion' means to be a member of a religious institution, but it does not refer to religious feelings or values[43–45]. Furthermore, the Japanese do not make a sharp distinction between faith and superstition (the latter of which for them has no derogatory connotations) as Westerners do (Dr Bernhard Scheid, Department of Japanese Studies, University Vienna, Institute for the Cultural and Intellectual History of Asia, personal communication, December 16, 2011). Thus, it did not present a problem to ask a question concerning 'the belief in spirits in nature' for the purpose of this study (see subsection 'Sense of spirits in nature').

State-of-the-art of esthetics and spirituality as motivators for collective conservation activities

Studies on examples of collective conservation activities related to rural landscapes in Japan are rare[17,47–49]. Publications on the (*Tanada*) Ownership System pertain to its general structure, sustainability and procedural implementation and its role in conservation, but are available almost solely to the Japanese-speaking scientific community[26,28,50–55]. Several publications can be found dealing with the Japanese concept of nature and landscape preferences of different land users[29,31,35–39,41,42,56–64], and with the link between nature, esthetics and religion[12,13,29,31,39,65]. To our knowledge no international literature that discusses the connection between the esthetic and spiritual dimension and the motivation of people participating in collective activities for the conservation of traditional land use systems exists to date. This article follows a previous paper, where the general profile of the 'Ōyamasenmaida Ownership System', the major motivation of the volunteers and the transferability of this Japanese type of voluntary farm work activity to Western countries have already been discussed[28]. In this article, we focus on the role of esthetic appreciation and attitude toward spirits in nature and compare tenants and visitors (tourists just staying for a relatively limited time period). By means of an integrative research approach, we wish to provide not only an original contribution to science but also recommendations for the practical mobilization of volunteers for collective action aiming at the conservation of rural landscapes and their biodiversity. The volunteers in the Ownership System in Ōyamasenmaida call themselves '*ōnā*', derived from the English word 'owner'. As the Ōyamasenmaida Ownership System is a land tenure system, we have decided for the sake of clarity to use the term 'tenant' instead of '*ōnā*'.

Research Design, Methods, Data and Study Site

Research design, research questions and hypotheses

The research design (see Fig. 1) shows the overall research question which encompasses four questions:

(1) What is the motivation of tenants to engage in the Ownership System and of the visitors to see Ōyamasenmaida?
(2) What do both groups regard as the most important landscape attributes in Ōyamasenmaida?
(3) How do they perceive the landscape?
(4) What is the attitude toward nature spirits among tenants and visitors?

These questions will be answered by a comparison of the 'active' (tenants) and 'passive' (visitors) land users in Ōyamasenmaida. Their motivations and the underlying values will be surveyed based on two similar questionnaires (including photo-based landscape assessments for the tenants). We have four hypotheses:

(1) The attractiveness of the rice terrace landscape scenery plays a key role in the readiness of the tenants to engage in conservation activities and of the visitors to see the site.
(2) The attractiveness of the rice terrace landscape scenery is an important landscape attribute for the tenants and visitors.
(3) The traditional rural landscape (*satoyama*) is often perceived as (untouched) nature.
(4) Visitors and tenants imagine differently how this 'nature' is inhabited by spirits.

A case study approach was determined for this study, as the research is of an exploratory nature and addresses a contemporary phenomenon within its real-life context without clear borders between phenomenon and context[66].

Connection between esthetic and spiritual values and voluntary action for biodiversity conservation

(1) What is the motivation of the tenants to engage in the Ownership System and of the visitors to come to see Õyamasenmaida?
(2) What do both groups regard as the most important landscape attributes in Õyamasenmaida?
(3) How do they perceive the landscape?
(4) What is the attitude towards nature spirits among tenants and visitors?

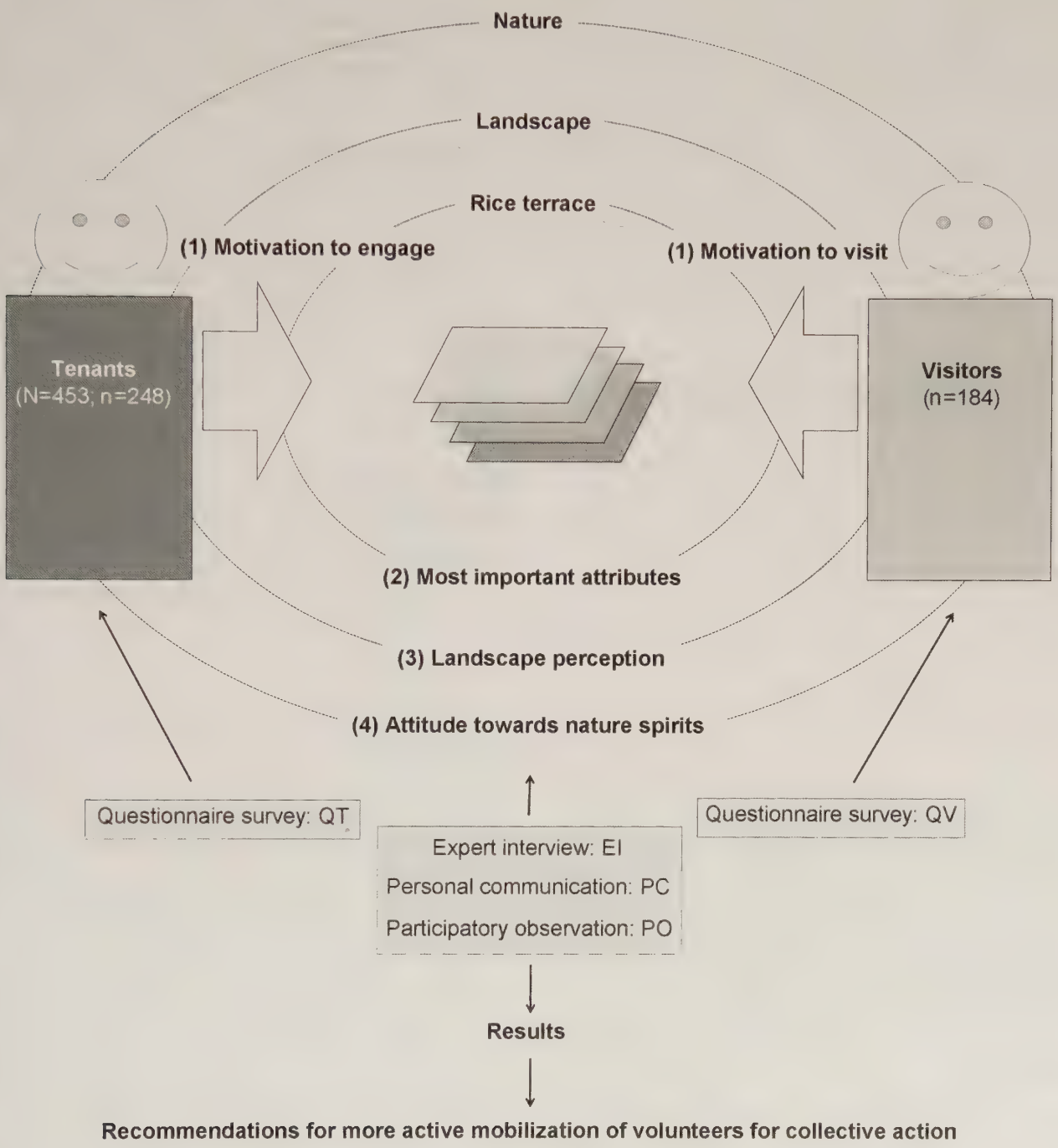

Figure 1. Research design.

Data collection

For this study, in total more than 50 days (December 2004–May 2006) were spent by the corresponding author on the site, taking part in various general and tenant meetings, tenants' working days (e.g., rice planting, weeding and harvesting), traditional cultural events, festivals and everyday life. It was by no means simple to become acquainted with the local people on site. As they were not accustomed to a foreign woman researcher, not only did general communication difficulties present an obstacle, but it also took nearly 1 year until they trusted her and lost their reservations to talk. After this warming-up phase, however, the 'Ōyamasenmaida people', particularly those from the Preservation Association, supported the study wholeheartedly.

The focus of this article lies in the information collected with structured questionnaires. The questionnaire survey is a cross-sectional comparison of two groups at a single point in time. Additional qualitative data are the results of the expert interview (EI), personal communication (PC), and participatory observation (PO).

Based on PC, PO and first explorative interviews with tenants and representatives of the local Ōyamasenmaida Preservation Association (PA), two questionnaires were designed in English for the two groups of 'tenants' (QT) and 'visitors' (QV), discussed with colleagues from the University of Tōkyō and then translated into Japanese. As e-mail addresses were mostly unknown, the questionnaires were distributed and collected directly on site (visitors and tenants at meetings) or sent by post, together with a stamped envelope for reply. Names and postal addresses of the tenants were provided by the PA. In a cover letter, the head of the PA motivated the tenants to participate in the study.

The questionnaires include questions on attitude, behavior and classification in an open, semi-closed and closed style. The open answers were transcribed and translated from Japanese into English. Direct quotations by the tenants or visitors recorded in the questionnaires or the statements from the EI with the director of the PA are therefore, in most cases, translations from Japanese into English. The translation from Japanese into English (particularly of the open statements in the questionnaires) was at times difficult, as Japanese is a very context-dependent language and the meaning of single short sentences is not always easy to grasp.

Study site

The case study looks into the (*Tanada*) Ownership System of Ōyamasenmaida, a traditional rice terrace landscape covering an area of 3.1 ha[67] in the midst of the hills on the Bōsō peninsula, around 15 km west of Kamogawa City and 100 km south-east of Tōkyō . In 1999, the rice terraces of Ōyamasenmaida were designated by the government as one of the 'Top 100 Terraced Paddy Fields of Japan'[27]. Before this designation, the landowners were already aware of the particularity of their rice terraces and in 1997, together with the locals, founded the NPO Ōyamasenmaida PA (PC: director, June 18, 2005). In order to secure the future management—eight of the 11 proprietors were already at retirement age—the PA drew up an Ownership System, which started officially in 2000 (PC: director, June 18, 2005).

The Ownership System of Ōyamasenmaida offers five different programs for rice, soybean, cotton/indigo and rice wine, respectively, and also organizes traditional dancing, cooking, and handicraft events and nature experience 'classes' (e.g., firefly watching) open to everyone[28,68].

Through its closeness to Tōkyō as well as through the popularity of Ōyamasenmaida, nurtured not least through documentaries and advertising campaigns (PO: April 2005 and November 2010; PC: informant A and B September and November 2010), the run on it is enormous (EI: director, June 18, 2005). Even the Emperor of Japan has already been there[69]. This is why the Ownership System gradually increased to more than 4.5 ha[67], partly adjacent to the main area, partly also on other sites around 1 km away (unpublished data; PO: October 16, 2005).

Principal Findings

In this section, we seek to compare the motivation of the 248 tenants and 184 visitors to engage in the Ownership System or to visit Ōyamasenmaida, and their underlying esthetic and spiritual values.

Motivations

The conservation of the traditional rural landscapes is of great importance for visitors and tenants alike. Of the 241 tenants, 238 (98.8%) believe that traditional rural landscapes such as Ōyamasenmaida have to be maintained ($n = 248$, n.a. = 7). Agreement in favor of maintenance among the visitors lies at 97.6% (164 persons) ($n = 184$, n.a. = 16).

The main motivations for participation in the Ownership System (Fig. 2) are simply 'love' for the rice terraces (119 affirmations, 50.2%), 'being close to nature', and 'taking part in the PA' (105 and 102 affirmations). The conservation of the rice terraces itself lies in fourth place. From an economic point of view, the Ownership System has no real relevance as a straight food production system, since the size of the fields is relatively small and the self-produced food altogether comparatively costly—it would be cheaper to buy the rice in the supermarket. This is possibly also an explanation for why only 10 persons indicate that their participation is directly due to the production of rice, soybean or rice wine and dyeing. Even if the self-produced goods are not the key impetus for participation, it can be assumed that they are an

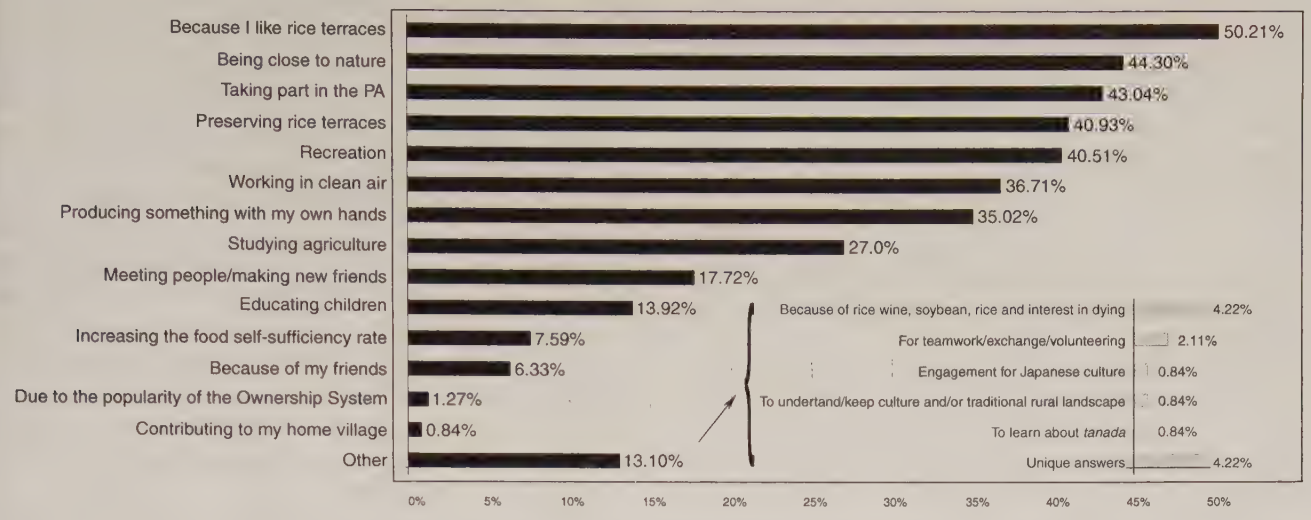
Because I like rice terraces 50.21%
Being close to nature 44.30%
Taking part in the PA 43.04%
Preserving rice terraces 40.93%
Recreation 40.51%
Working in clean air 36.71%
Producing something with my own hands 35.02%
Studying agriculture 27.0%
Meeting people/making new friends 17.72%
Educating children 13.92%
Increasing the food self-sufficiency rate 7.59%
Because of my friends 6.33%
Due to the popularity of the Ownership System 1.27%
Contributing to my home village 0.84%
Other 13.10%
Because of rice wine, soybean, rice and interest in dying 4.22%
For teamwork/exchange/volunteering 2.11%
Engagement for Japanese culture 0.84%
To undertand/keep culture and/or traditional rural landscape 0.84%
To learn about tanada 0.84%
Unique answers 4.22%
0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50%

Figure 2. Tenants' motivation for participating in the ownership system (897 valid answers from 237 persons) given in average numbers (figure based on Kieninger et al.[28]). The question is semi-open (the indication of a maximum of five reasons for participating was allowed). Apart from the 14 preformulated answer categories, there was also the possibility to provide an individual answer. These open answers were coded and are shown together with the respective percentages on the right-hand side of the figure.

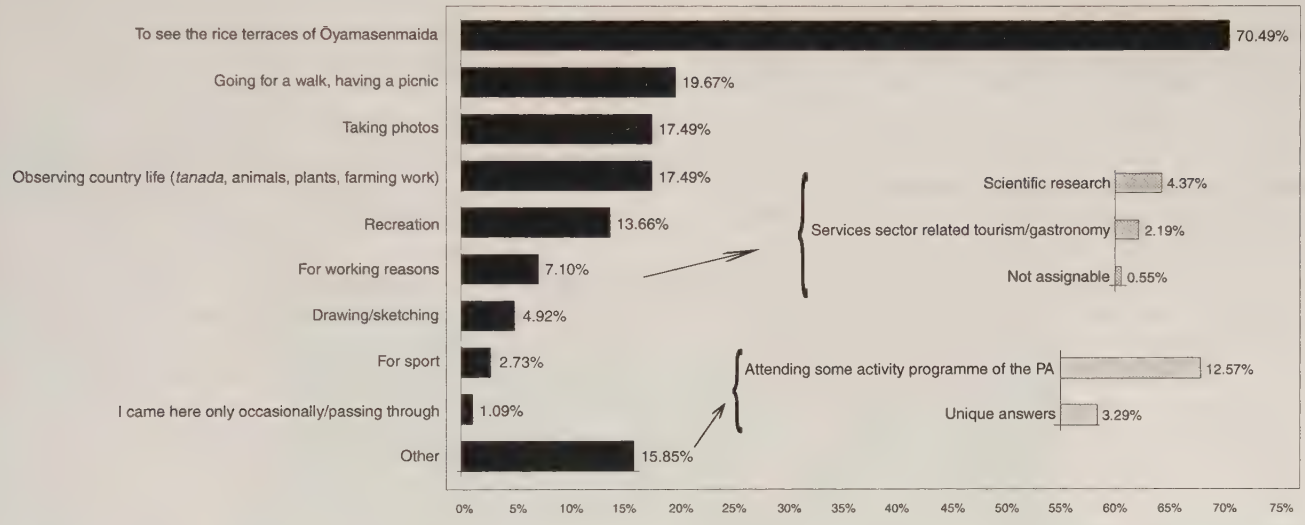
To see the rice terraces of Ōyamasenmaida 70.49%
Going for a walk, having a picnic 19.67%
Taking photos 17.49%
Observing country life (tanada, animals, plants, farming work) 17.49%
Recreation 13.66%
For working reasons 7.10%
Drawing/sketching 4.92%
For sport 2.73%
I came here only occasionally/passing through 1.09%
Other 15.85%
Scientific research 4.37%
Services sector related tourism/gastronomy 2.19%
Not assignable 0.55%
Attending some activity programme of the PA 12.57%
Unique answers 3.29%
0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75%

Figure 3. Visitors' motivation to come to Ōyamasenmaida (312 valid answers from 183 persons) given in average numbers. The question is semi-open (the indication of a maximum of five reasons for participating was allowed). Apart from nine preformulated answer categories, there was also the possibility to provide an individual answer in the category 'other' and 'for working reasons'. The open answers are shown together with the respective percentages on the right-hand side of the figure.

important 'by-product' with an ideal value, which the tenants are proud of: 'They eat the harvested products themselves or give them to friends on special days, e.g. on commemoration days or for their friends' party.' (EI: director, November 14, 2010).

The main reason (70.5%) why the visitors come to Ōyamasenmaida is to see the rice terraces (Fig. 3). Almost all of the other reasons have some connection with the rice terraces too. Among the open answers the attendance of traditional cultural events such as sushi-, tofu- or miso-producing festivals prevails. These 'festivals' are traditional events related to the cultivation of rice and soybeans (on some of the rice terraces soybeans are grown[28]), and the visitors come to experience them in the authentic 'environment'. In summary, 92.6% of the visitors come to Ōyamasenmaida because of the terrace landscape.

Esthetics

Attractive attributes of Ōyamasenmaida deserving protection. In order also to obtain an insight into the local attributes most attractive to visitors and tenants, they were asked to select from a list of predetermined

Table 1. Important traditional rural landscape attributes from the viewpoint of visitors ($n = 184$; 17 persons chose one attribute, 32 two and 120 three; n.a. = 15) and tenants ($n = 248$; six persons chose one attribute, 72 and 195 three; n.a. = 40). *P*-values given for the Pearson's chi-squared test with Yate's continuity correction; *P*-values for significant terms at the 0.001-level are given in bold.

	Visitors	Tenants	*P*-value (χ^2)
Scenic landscape beauty of the rice terraces	84.02%	63.00%	**<0.001**
Entire landscape with rice terraces, mountains, forests, etc.	63.91%	51.92%	0.025
Harmony of man and nature	30.20%	46.63%	0.002
Typical *satoyama* fauna, such as birds, frogs, salamanders, butterflies, caterpillars and fireflies	6.51%	30.29%	**<0.001**

Other arguments: 'To activate regional economy' (QT 95); 'Croaking of the frogs' (QV 54 & 92); 'Culture' (QV 19); 'That Ōyamasenmaida is in good condition' (QV 31); 'Mr. Ishida [annotation: the director] is hard working and cheerful' (QV 51); 'Rain and the rice terraces' (QV 55); 'Company, meeting people, talking, community, making friends' (QV 72); 'Miso-making experience' (QV 117); 'Rice terraces prevent landslides' (QV 170); 'The activity to vitalize this area' (QV 179).

answers what they regard as most impressive (visitors) or most important to conserve (tenants). A maximum of three answers was allowed. Visitors could choose from nine, and tenants from eight possibilities (Table 1). Additional personal comments were provided by 10 visitors and one tenant.

For both visitors and tenants the 'scenic landscape beauty, particularly the rice terraces' is the most attractive attribute [142 visitors ($n = 184$, n.a. = 15) and 131 tenants ($n = 248$, n.a. = 40); see also Table 1]. Also the 'entire landscape' (108 visitors and 108 tenants) and, thirdly, the 'harmony of man and nature' are very often mentioned, the latter, however, with a reverse weighting, as this attribute seems to be more relevant for the tenants. Clearly visible is the differing importance of the 'typical *satoyama* fauna, such as birds, frogs, salamanders, butterflies, caterpillars and fireflies' between tenants and visitors. For 63 tenants, the fauna belongs to the most important things to conserve in Ōyamasenmaida, but only 11 visitors regard it as the most impressive part of this landscape. This difference is highly significant.

Landscape perception. From Figure 4 it is clear that both groups perceive the landscape as beautiful: 223 tenants (97.81%) and 146 visitors (91.25%) describe the landscape of Ōyamasenmaida as 'beautiful' or 'very beautiful'; the tenants, however, give slightly higher, albeit significant, valuations, as they perceive 'their' landscape, the place where they work with their hands, as significantly more beautiful than the visitors just passing by. Significant differences can also be identified between the two groups regarding the 'inspiring quality' and the 'uniqueness' of the landscape. Very high agreement in numbers and on average (Fig. 4) can be detected on the landscape parameters 'harmony of man and nature' and 'traditional (landscape)'.

A very surprising result from a European point of view, and confirming our hypothesis that nature and cultural landscape (traditional rural landscape) are comprehended by Japanese people as a union, is that even though Ōyamasenmaida—a 1000-year-old rural landscape formed and shaped by humankind—is characterized by 83.78% of the tenants ($n = 248$; n.a. = 26) and 87.74% of the visitors ($n = 184$; n.a. = 29) as a traditional/very traditional landscape, it is described by a comparatively high number of tenants (27.95%; 64 of 248, n.a. = 19) and visitors (29.75%; 47 of 184, n.a. = 26) as a 'very untouched'/'untouched' landscape. The director of the Ōyamasenmaida Ownership System says this: 'The nature of Ōyamasenmaida is not the 'real nature'. People created it. ... It is not a mountain or a virgin forest without human influence, but a rice field made by humankind. ... In Minamiboso, Chibaken, Kamogawa there is no ... forest, which one can call a virgin forest. What the tenants define as nice nature is cultural landscape.' (EI: director, November 14, 2010).

Overall both groups perceive the landscape similarly.

Photo-based landscape evaluation. A photo of an 'ordinary' contemporary Japanese paddy field (Fig. 5) was inserted in the questionnaire. The tenants were asked in a closed question (yes/no) whether they would participate in the activities of the PA if the Ōyamasenmaida landscape (Fig. 6) resembled that shown in Figure 5; in a second step they were asked to explain their decision in an open answer with 'why yes/why no'.

Of the 225 respondents ($n = 248$, n.a. 23), 82.22% would cease their participation in Ōyamasenmaida if the landscape resembled Figure 5, while 17.77% (13 female and 27 male) would continue. The open answers were translated and coded (Figs. 7 and 8). The most frequent category (36.17%) of 'Yes, I would participate because...' (Fig. 7) is: 'I would like to experience and/or support agriculture'. For these interviewees, the agricultural activity itself has priority rather than the environment or landscape, e.g., 'I think the agricultural activity would be the same' (QT 28). 'The main purpose was to experience farming activities for myself' (QT 34). 'It is still connected to agriculture' (QT 204). 'My interest is in agricultural production. If the area is large, I will participate [by cultivating] a part of it' (QT 219).

The second most frequent categories expressing acceptance were: 'This landscape is also nice and/or it is also nature' and 'My main focus is not *tanada* and/or nice scenery' (each with eight answers). These tenants regard the rice field shown in Figure 5 as a good place of nature or rather state directly that the main focus of their participation in Ōyamasenmaida is not nice scenery or

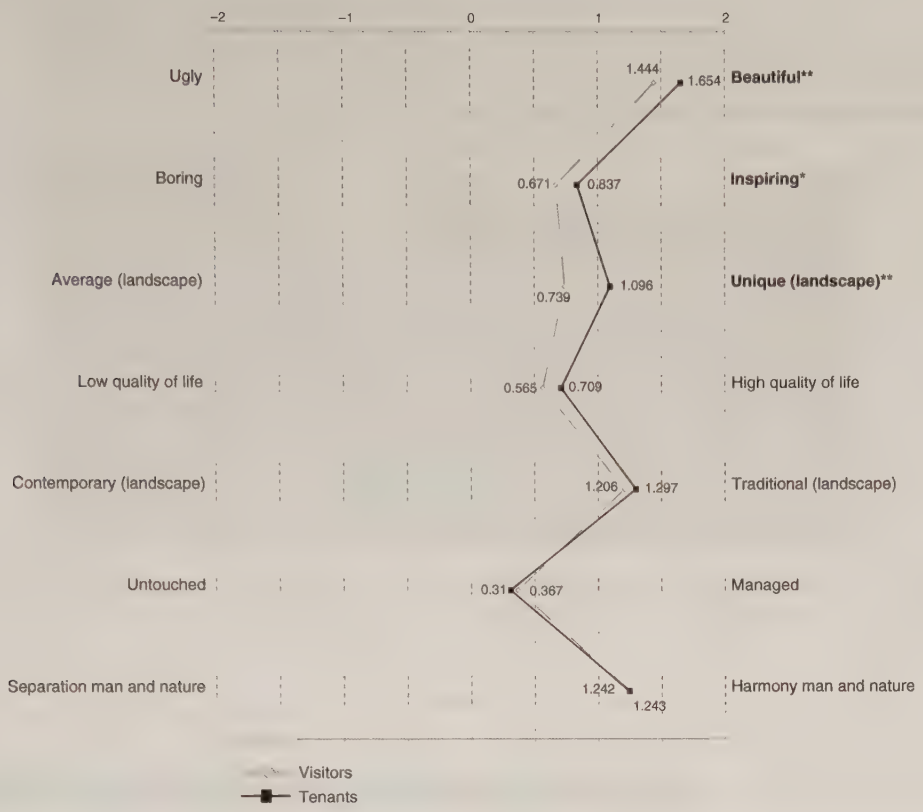

Figure 4. View of tenants and visitors regarding different landscape parameters, measured with the semantic differential on a 5-scale bar[70]. In a *t*-test, significant differences in the landscape perception of Ōyamasenmaida between visitors and tenants can be found for the parameters 'boring–inspiring', 'standard–unique (landscape)' and 'ugly–beautiful'. Significant differences between mean values are marked with *, if significant at the 0.05 level, and with **, if significant at the 0.01 level.

Figure 5. In contrast to the rice terraces of Ōyamasenmaida (Fig. 6) this paddy field (Chiba prefecture) is comparatively large. It lies in the plain and is located adjacent to a bicycle/footpath and a straight single lane road.

tanada: 'Yes, I would participate because': 'I am interested in agriculture and nature, even if it is not *tanada*.' (QT 36), 'Landscape is great.' (QT 127), 'I want to get in touch with nature.' (QT 146) or 'I would like to experience agriculture itself rather than merely enjoying the scenery' (QT 153), etc.

Figure 6. The *tanada* landscape of Ōyamasenmaida is located in the midst of the hills (80–150 m above sea level). The size of the terraces ranges from 20 to 900 sqm[67]. Forest and bamboo groves are in the background. The road skirts the terraces on the right.

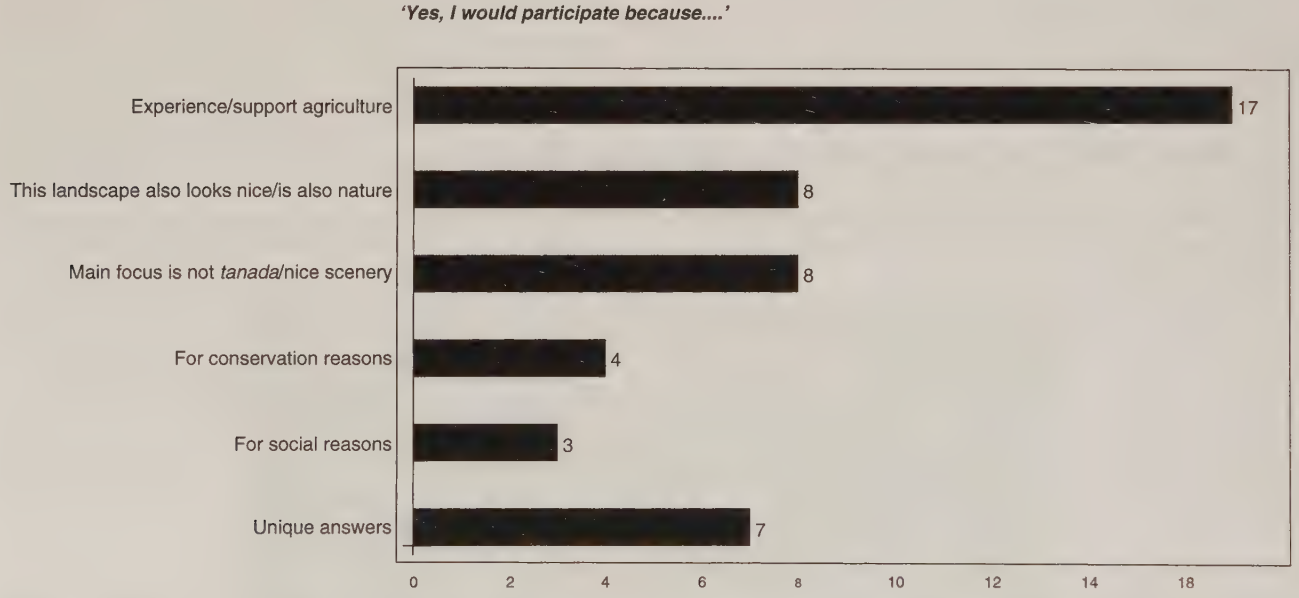

Figure 7. Reasons for continuing the ownership system on a paddy field such as the one shown in Figure 5 (47 arguments from 35 people).

Most prevalent among 'No, I would not participate because...' (Fig. 8) is with 21.47% of the category 'Common place and/or not attractive', followed by, and often linked to 'It's not a *tanada* landscape' (19.41%), e.g., 'I can see this kind of landscape anywhere. If it were not *tanada*, there would be no special reason to visit Ōyamasenmaida.' (QT 17), 'In my neighborhood there are paddies, but I am attracted by *tanada*.' (QT 71), 'Such scenery can be seen in my neighborhood. One of the main reasons why I am participating in the activity is that *tanada* has the most attractive landscape.' (QT 76).

The third most important point for the tenants is handwork (14.71%). As they want to experience agricultural work manually, large and industrialized fields such as that in Figure 5, where machines can be used for work, are of no interest to them, e.g., 'The charm of *tanada* is to experience nature without machines.' (QT 94), 'This field can be cultivated by machines and the agricultural environment can therefore be maintained.' (QT 173), 'I wanted to obtain experience in agricultural handwork in a rice field, where animals and plants live together.' (QT 200), 'This area is more suitable for machines. *Tanada* can only be cultivated by hand. It is important to protect the heritage of our ancestors and the cultural landscape. I could bring my children and grandchildren to learn to work with their hands. It is very

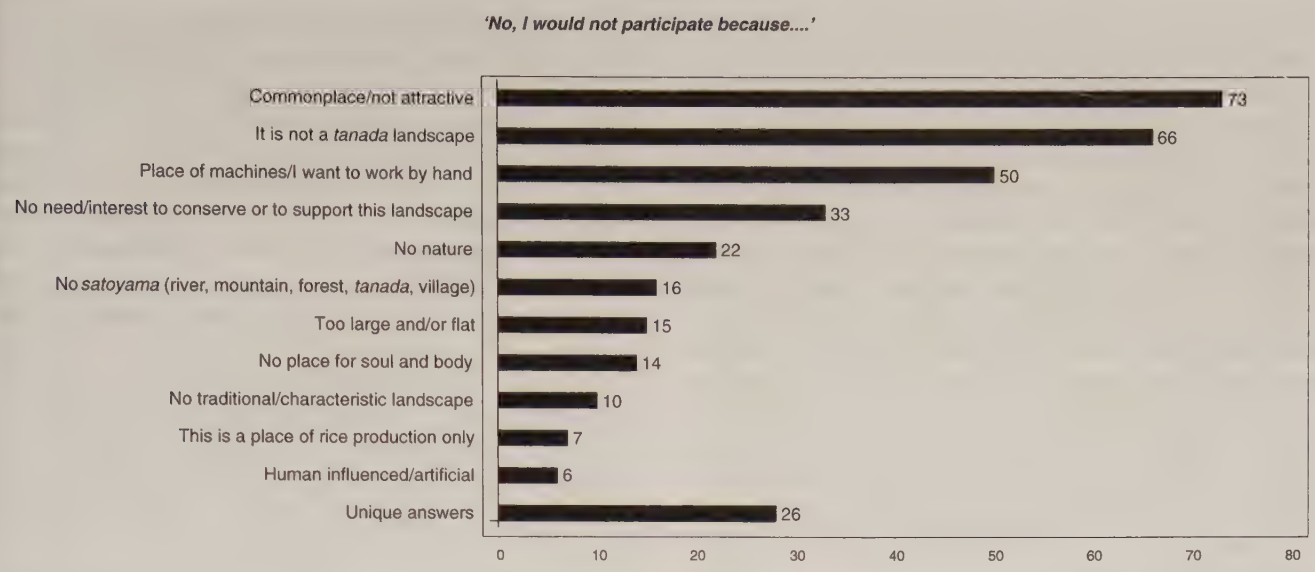

Figure 8. Reasons for ceasing participation if Ōyamasenmaida resembled the plain paddy field shown in Figure 5 (340 arguments from 168 people).

important that children see that handwork is exhausting.' (QT 211), '*Tanada* landscape is important. Working with machines is no fun. To become active in agriculture is not my goal.' (QT 221).

The evaluation of the picture clearly shows that beautiful scenery is a highly relevant motivator for the tenants. Scenic beauty is thereby tightly linked to *tanada*, cultivated in the traditional way by hand. Plain, large and mechanized fields are neither accepted nor are they considered by most of the tenants as something worth protecting or supporting: 'The *tanada* landscape seems to me the archetypal scenery of Japan. I am not attracted to places like the one on this photo, which is not *satoyama.*' (QT 163), 'Different from *tanada*, the scenery is flat and not interesting.' (QT 206), 'I didn't just want to engage in agriculture/farming but I was also very interested in the unique scenery of senmaida and its protection.' (QT 226). Also, the director of the Ownership System confirms a certain preference of the tenants for a rice terrace landscape: '... they want to participate [in the Ownership System] in a nice landscape, such as Ōyamasenmaida. Thus ... as the city dwellers themselves partake in the Ownership, as they become tenants and take part, thus, the magnificent beautiful landscape is conserved. That is joyful for the city dwellers, for the tenants' (EI: director, November 14, 2010).

Spirituality

In the last question in the questionnaires we asked tenants ($n = 248$, n.a. = 14) and visitors ($n = 184$, n.a. = 18) whether they have a certain 'feeling' for spirits in nature: 'Do you ever have the feeling that in certain parts of nature such as, for instance, in the mountains, valleys, rice terraces, orchards, streams, lakes, plants, and trees, some kind of spirits live?' We use the term 'spirituality' for the 'belief' in spirits (deities or other immaterial, mystical or mythological beings/powers) inherent in nature. It could be questioned, whether 'to feel spirits' means to believe in them (PC: Dr Brigit Staemmler, Department of Japanese Studies, University Tübingen, January 13, 2012). We use 'belief' in the sense defined by Merriam-Webster, which is: 'belief is a mental acceptance but may or may not imply certitude in the believer'[71].

Two hundred and thirty-four tenants and 166 visitors gave an answer to this question on a five-point scale from 'always', 'often', 'sometimes', 'rarely' to 'not at all'. Additionally, even if not intended, three tenants and one visitor added personal annotations e.g., 'Everything is divine.' (QT 223), 'All nature's workings are divine secret.' (QT 215), 'I believe in spirits in the mountains, valleys, terrace fields, little rivers, plants and trees, but not in lakes and orchards.' (QV 94).

More than half of the tenants (133 persons, 56.84%) have an impression of spirits in nature (18.8% always, 14.53% often, 23.5% sometimes), while 19.66% rarely and 23.5% do not believe in them at all. If we compare this result with the visitors' sample, we can see that in this group the feeling of spirits in nature (always–sometimes) is a bit lower, by 50%. A significant difference can be identified regarding 'I always have the feeling of spirits in nature' between tenants (men and women, 18.8%) and visitors (men and women, 9.64%) ($P = 0.017$) and a highly significant difference between $\text{tenant}_{\text{women}}$ (25.86%) and $\text{visitor}_{\text{women}}$ (8.43%) ($p = 0.010$).

With these results, our hypothesis of a link existing between 'spirituality' and participation in voluntary nature conservation activities such as the Ownership System can be partly confirmed. Partly, because the differences are apparent only in the category 'I always

have the feeling of spirits in nature'. The reason, therefore, cannot be explained completely. The director of Ōyamasenmaida argues that the belief in the 'great nature' (spirits) is a result of their own food production: 'Not necessarily only *tanada*, but the villages and the whole rice culture (in general) have a religious meaning. In the Japanese religion the whole of nature, everything, is *kami-sama*. The sun, the stones, the trees, the earth, the water, everything is *kami-sama*. Since the idea of nature as *kami-sama* is in the hearts of the Japanese people, it is not necessarily the case that particularly rice terraces have such a connotation.... People who live in the cities (don't know) that food is influenced by nature, from nature.... People who participate in the Tanada Ownership System understand this. If you live in the city and you buy food with money, you don't realize it. But if you participate here, you understand that food is cultivated in nature while it is influenced by nature. And then they perhaps think that nature in this sense is magnificent.' (EI: director, November 14, 2010). However, a connection between duration of participation in the Ownership System and an increased belief in spirits among the tenants cannot be found in our results. Also, concerning age there is only a slight difference between tenants and visitors (52.25 years tenants versus 47.8 years visitors) in the category 'I always have the feeling of spirits in nature'.

The above-mentioned highly significant difference between $tenant_{women}$ and $visitor_{women}$ in the category 'I always have the feeling of spirits in nature' is remarkable. Regarding age, no difference can be found between these two groups ($tenant_{women}$ 47.46 years, $visitor_{women}$ 45.17 years). An age difference can therefore also be excluded as a reason here.

Discussion

'From beauty to duty'[72]

It has often been proved that esthetically appealing 'objects' such as landscapes, animals or plants create a deeper attachment and greater respect toward nature, influencing people to act in an environmentally friendly manner and to engage in nature conservation[29,31,72,73]. This is the case in many countries, not only in Japan. For example, in the USA, the designation of national parks and wilderness protection in the 19th and 20th centuries was based mainly on esthetic nature appreciation[31,72]. The esthetic quality of a certain site can even be increased by a 'label of scenic designation'[74]. This happens easily in countries with a collectivist worldview[75]. In our study, we asked about the motivation of the tenants to engage in the Ownership System and about the motivation of the visitors to see the site, as well as about the most important landscape attributes. We hypothesized that the attractiveness of the rice terrace landscape scenery played a key role and was an important landscape attribute. Both of these hypotheses could be confirmed.

As Ōyamasenmaida, after its designation to the 'Top 100 Terraced Paddy Fields of Japan', was advertised in audio-visual and print media, the number of visitors, often in organized groups, increased rapidly. With a relatively limited length of their stay, their main motivation is to visit the site in order to appreciate the terrace landscape scenery. For the tenants, the situation, however, is a bit different. Even if the catalyst to engage as tenant possibly originates from the landscape beauty of Ōyamasenmaida—Hettinger[76] calls this 'aesthetic protectionism'—the initial stimulus for participation in the Ownership System changes later from a pure 'scenery obsession'[72] to a larger environmental view. Although for both, tenants and visitors, the landscape scenery ranges in the first rank, tenants consider the protection of the typical *satoyama* fauna significantly more important than the visitors do (30.29% versus 6.51%).

For the visitors, Ōyamasenmaida might 'only' be one destination among many (3/4 of the visitors know or have already visited similar landscapes before). The tenants, however, through their working commitment, their emotions, social contacts, the sounds and scents of the site, and their memories and thoughts became emotionally attached to this place. That is why they perceive Ōyamasenmaida as significantly more beautiful, more unique and a more interesting place. This finding was also observed by other scientists[77,78]: 'When we care about an object of appreciation, we become interested in it. Accordingly, this interest motivates us to look for the object's aesthetic value'[73]. The benefits and disadvantages of esthetically grounded environmentalism are discussed controversially in the scientific community[29,31,73,76,78,79], whereby it is often maintained that for sound environmentalism, nature appreciation needs to be serious and morally based and has to change from subjectivism to objectivism, from ego- or anthropocentrism to acentrism, from a scenery (and flagship-species) focus to an environmental focus[31,72]. However, we think that in order to attract people unconcerned with environmental issues, a less scientific but more emotional approach[80] would be a more promising way, also outside of Japan. 'Frequently, one of the main reasons for supporting environmental causes is to preserve beauty. Average citizens wish to preserve scenic landscapes, flowering plants, and attractive animals and will donate their money and sometimes their time to working toward such ends'[73]. This can also be shown in our study: 82.22% of the tenants would cease their participation, if the landscape of Ōyamasenmaida were a large, plain, mechanized paddy field. From this point of view, the bias for nature's beauty should not be dismissed as superficial, but rather seen as an opportunity to attract the interest of potential activists first. Later on, their esthetic appreciation could expand to ecological aspects. This has been successfully demonstrated in Ōyamasenmaida. Starting with a rural–urban exchange of people, collective cultivation and production of rice, soybeans, rice wine, arts and crafts lectures, and

common feasting, the PA also tries to arouse the tenants' interest in ecological issues, e.g., the life cycle of fireflies.

Reflecting on the motivations driving voluntary activities for nature conservation, we can state that the tenants were motivated rather by needs belonging to Alderfer's categories[81] of growth (including the need for self-development and personal growth and advancement) and relatedness (interpersonal relationships and getting public recognition) than by the actual existence needs, such as quality food or food security.

Taming and cultivating is natural

The Japanese understanding of nature, a result of the interconnection between esthetics and religion since ancient times, has formed the conception of nature and man as a unity[34], where human influence is hardly viewed as an intrusion into nature. 'Only when nature is brought into the realm of the known, e.g. tamed, and there are some immediate personal gains, do most Japanese become interested in protecting nature'[32]. Accordingly, we assumed that the Japanese might consider a cultural landscape as untouched nature (hypothesis 3). We could verify this hypothesis, as more than one-quarter of the tenants and visitors perceive the terraced rice terraces of Ōyamasenmaida as untouched/very untouched nature. For this result, we also get support from the literature. Takeuchi reports that the traditional rural landscape in Japan (*satoyama*) is often regarded as original or untouched nature[4].

Sense of spirits in nature

'Measuring' religiosity or spirituality, particularly in a different cultural context, is difficult and can lead to wrong conclusions. As already mentioned in the Introduction, religiosity and/or spirituality have a different meaning in Japan as opposed to the Western world. In order to avoid this problem, our research question centered on the attitude of tenants and visitors toward nature spirits and we cautiously asked 'only' about the general acceptance of the existence of spirits in nature. It can be considered as a main result that 94.35% of the tenants and 90.22% of the visitors did not hesitate to answer this question—a sign that this query did not seem strange or non-sensical to them.

Most of what has been written by different authors up to now about Japanese religiosity reflects their own insights or imagination[46]. Empirical studies are still rather few[46]. Nevertheless, a Japanese scholar found out that out of 1800 respondents, 30.8% agreed '...that souls inhabit everything, such as mountains, rivers, grass, and trees'[46]. Our research question is very close to this. Also, in the Tenth Annual Japanese Character Study from 2000, cited by Stark et al., 59% of the interviewees answered that they feel that rivers and mountains have spirits[44]. In our study, 56.84% of the tenants and 50% of the visitors (always, often and sometimes) have the feeling that spirits exist in the mountains, valleys, rice terraces, orchards, streams, lakes, plants and trees. If we add the number of persons who have this feeling 'rarely', we even reach as much as 76.5% among the tenants and 72.89% among the visitors. This high rate of belief in nature spirits is surprising. However, the limitation of a cross-sectional study, namely the impossibility to distinguish between cause and effect due to a lack of observation over time, becomes particularly evident here, as we have no distinct explanation for the causality of the belief in spirits in nature among tenants and visitors. It could be possible that the special atmosphere (peace, silence, nature, nice landscape and, in the case of the tenants, handwork) of Ōyamasenmaida had an influence on the respondents' answers and that questioning of the same people, but in the loud and hectic conurbation of Tōkyō, would have led to different results (PC: Dr Birgit Staemmler, January 26, 2012).

Our hypothesis that tenants and visitors imagine differently the way in which nature is inhabited by spirits can be partly confirmed, as significant differences appear only in the category 'always'. Our assumption that, in contrast to the visitors, who just passed through, the feeling of nature spirits had developed more strongly among the tenants through their long-term involvement could not be confirmed in our research. With respect to age, tenants and visitors do not differ significantly, so that age difference as a reason for this phenomenon can also be excluded. One interpretation for our study could be that the tenants participate because they already have a certain tendency toward traditions and the will to return to nature, to the roots of Japanese culture (PC: Dr Birgit Staemmler, January 26, 2012). Cultivating rice is a good possibility to satisfy these feelings and the belief in nature spirits, in transcendence and otherworldliness is very close to this mental attitude (ibid.). The director of Ōyamasenmaida argues that the tenants became more receptive to *kami-sama* on account of producing their own food in the midst of 'great nature'.

Also unanswered is the reason for the highly significant difference between female tenants and female visitors in the category 'I always have the feeling of spirits in nature'. It can be assumed that among women a high spirituality appears more strongly in direct action (e.g., in participation in the Ownership System) than it is among men, so that the significant differences in our case become obvious only between the female tenants and female visitors.

Conclusions

The case of the Japanese Ownership System indicates that esthetic landscape appreciation can help mobilize an involvement in nature conservation activities. The interviewed volunteers in Ōyamasenmaida are rather more motivated by intrinsic reasons (most of all by the landscape esthetics, but also by nature experience,

learning, hand work and socializing with like-minded) than by extrinsic ones (e.g., physical need to produce food, social pressure or approval from outside). Through able guidance (such as that provided by the PA in our case study) which also addresses emotion and fun—through traditional music, theatre and dance festivals, photo awards (for the yearly Ōyamasenmaida calendar), sport events (e.g., 'mud' volleyball competition in the rice fields), feasting (karaoke singing and harvest festivals), local food or handicraft workshops, renovation of old traditional houses for common purposes or collective nature experiences (fireflies, autumn moon and torch illuminated rice fields)—the volunteers could develop a broader ecological awareness. In consequence, their interest would also extend to other less attractive places. In Western countries (mainly in Central Europe or North America), nature conservation still works on a more scientific level, mobilizing volunteers through scientific evidence on, for example, losses of species or biodiversity. To also address the motivation of the volunteers on an emotional, esthetic or social level could be a promising way forward.

The extent to which spirituality is the cause for or an effect of active involvement in nature conservation activities cannot be derived from this survey. The subject of future studies could therefore be the question concerning the connection between spirituality (and religiosity) and the engagement in nature conservation activities. Even if a lot of international literature can be found related to the attitudes of religious persons in different fields of life—also those including environmental concerns—none of it addresses the question as to whether spiritual/religious motivation is the reason for engaging in nature conservation activities or whether the engagement itself results in spiritual/religious awareness.

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Weeds and endangered herbs have unforeseen dispersal helpers in the agri-environment: gastropods and earthworms

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Accepted 11 December 2012; First published online 11 February 2013 **From the Field**

Abstract

Agri-environmental schemes involving organic farming or set-aside management aim at promoting biodiversity and restoring ecosystem functioning in agrarian landscapes. Application of pesticides in these crop fields is strongly regulated facilitating the spread of weeds but also allowing for the establishment of endangered herbs and a variety of animals. Recent studies found gastropods and earthworms to be legitimate dispersers of seeds of wild plants. We assumed that both groups also play a significant role in the spread and establishment of wild plants within crop fields. Therefore, we are conducting a series of experiments in three different study systems on (1) the role of earthworms and gastropods as dispersers of rare herbs and weeds in an organic rye field in Germany, (2) the seed feeding behavior of gastropods of plants sown in fallow ground in Switzerland, and (3) weed dispersal in irrigated rice fields by golden apple snails in the Philippines.

Key words: seed dispersal, slugs, snails, crop field, feeding trial

Introduction

In the course of agricultural intensification, farmland biodiversity has declined due to the decrease of semi-natural habitats in agrarian landscapes and the increased application of pesticides and fertilizers, impairing a variety of ecosystem functions and services[1]. Different approaches of agri-environmental management have been found to successfully restore biodiversity[2]. Plant diversity that provides habitat and food for animals can be established at the border of crop fields by set-aside management, e.g. wildflower strips, or within crop fields. Common weeds and rare arable herbs both profit from non-intensive or organic farming. While rare herbs are sown intentionally to strengthen their populations, weeds will colonize fields reducing crop yield[3]. Seed dispersal is essential for the viability and competitiveness of arable plant populations[4]. Most arable plant species, however, lack obvious adaptations for dispersal and rely on gravity when shedding their seeds[4], which permits very limited dispersal distances unless seeds are transported by man[3]. Recent research highlights the importance of so far

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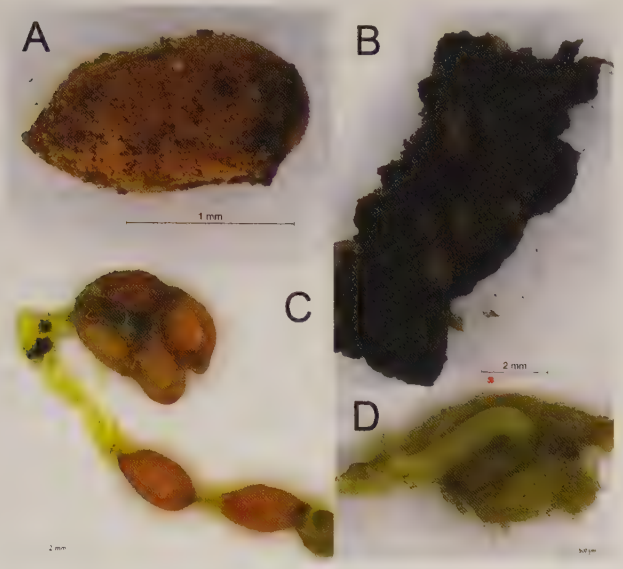

Figure 1. Seeds of field pansy (*Viola arvensis*) in (A, B) earthworm casts (*Lumbricus terrestris*) and in (C) slug feces (*Arion lusitanicus*), and (D) a seed of German chamomile (*Matricaria recutita*) germinating from slug feces.

underappreciated invertebrate taxa, in particular, gastropods[5] and earthworms[6] in the dispersal of seeds of herbs. Also in crop fields or adjacent wild flower strips, gastropods were responsible for the removal of a fair proportion of weed or herb seeds[7,8]. We are conducting experiments within three projects to test the potential of gastropods, and partly also earthworms, to disperse seeds and also to predate on seeds of agricultural weeds and rare arable plants by the ingestion of seeds. In the following, we briefly present the three projects, their aims and first findings.

The Projects

Weeds and rare herbs in an organic rye field (Germany)

We established an organically managed rye field in Germany to assess the effects of management and animals on the establishment of rare arable wild herbs. A number of weeds are growing naturally in the field. We conducted seed removal experiments with five weeds and three rare herbs (Appendix 1) with one treatment accessible to all animals and one treatment protected against rodents. In addition, we used video cameras to identify all seed-feeding animals. In accompanying laboratory experiments, we offered seeds to two slug and two earthworm species of up to 15 plant species (animal species-dependent), including 12 common weeds and three rare herbs (Appendix 1), followed by germination experiments. Slugs and earthworms readily swallowed seeds of different species and defecated them mostly apparently intact (Fig. 1). Seeds of several species germinated after being defecated. By screening the first videos, we observed rodents, carabids, earthworms and slugs visiting seed depots in the field, supporting the significance of interactions between seeds and the latter two invertebrate groups.

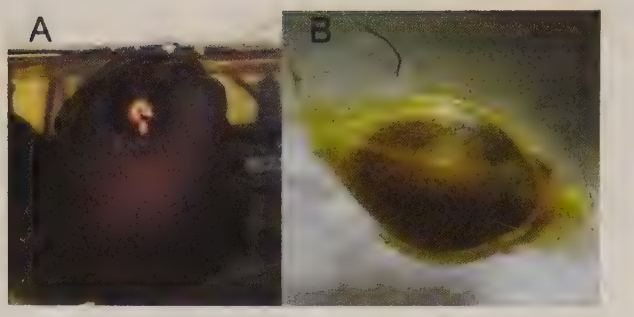

Figure 2. Seeds of common barnyard grass (*Echinochloa crus-galli*) (A) eaten by a golden apple snail (*Pomacea canaliculata*) and (B) collected from its feces.

Herbs sown in fallow ground (Switzerland)

In a lab experiment, we fed four different gastropod species (*Arion lusitanicus, Arion rufus, Cepaea nemoralis* and *Helix pomatia*) with five different herb species often sown in fallow ground in Switzerland (Appendix 1). Consumption and damage of seeds after gut passage were assessed; defecated seeds were collected and put on soil to evaluate germination rates. We found high consumption rates in all mollusc species and for all five plant species. Furthermore, the seeds that had previously been defecated showed high germination rates, similar to those without gut passage. Our results therefore support our hypothesis that molluscs act as efficient and important seed dispersers of a wide range of plant species in agricultural landscapes.

Weeds in irrigated rice fields (Philippines)

Rice farmers in South-East Asia make a great effort to fight weeds. Exotic golden apple snails (*Pomacea canaliculata*) were introduced to control weeds in rice fields, amongst other things[9]. In most cases, however, the snails were a major pest, consuming rice plants[9]. We suggested that this invasive snail might also be spreading weeds in rice fields. Within the LEGATO project on land-use intensity and ecological engineering in irrigated rice (http://www.legato-project.net/), we collected seeds of 12 common weeds in the Philippines (Appendix 1), which currently are being offered to snails in feeding experiments. First observations in the laboratory showed that the snails readily consumed seeds of the troublesome barnyard grass *Echinochloa crus-galli* and defecated them apparently intact (Fig. 2). We will further conduct seed removal experiments and observations in rice fields in the Philippines.

Outlook

Our complementary experiments in multiple settings will help us to understand whether gastropods and earthworms are important for weed movement and the establishment of sown plants in the agri-environment. Based on our findings, it is possible that invertebrates such as slugs that dwell in planted wild flower strips might affect crop yields negatively if they transport weeds into the fields, even if they do not feed on the crop. Thus, it might be valuable to establish structured habitats at crop margins which do not promote these invertebrates but their predators. In environments where seed dispersal is beneficial, such as in ecological restoration, knowing which seed traits encourage dispersal, and which animals are important in dispersal, would be beneficial. In consideration of our preliminary results, we suggest that future research on weed ecology, dispersal and predation should take these invertebrate groups into account.

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Appendix 1. Plant species of which seeds were/will be offered in field seed removal experiments (= Field) or to gastropods and earthworms in laboratory feeding trials (= Laboratory).

Project	Plant species		Common name	Family	Laboratory[1]	Field[1]
Germany	*Alopecurus myosuroides*	Huds.	Slender meadow foxtail	Poaceae	AL, LT, DV	
	Apera spica-venti	(L.) P. Beauv.	Silky bent grass	Poaceae	AL, LT, DV	
	Capsella bursa-pastoris	(L.) Medik.	Shepherd's purse	Brassicaceae	AL, LT, DV	
	Cirsium arvense	(L.) Scop.	Creeping thistle	Asteraceae	AL, DR, LT, DV	Yes
	Consolida regalis	S.F. Gray	Forking larkspur	Ranunculaceae	AL, LT, DV	Yes
	Elymus repens	(L.) Gould s. str.	Cough grass	Poaceae	AL, LT, DV	
	Galium aparine	L.	Cleavers	Rubiaceae	AL, LT, DV	Yes
	Legousia speculum-veneris	(L.) Chaix	Venus' looking glass	Campanulaceae	AL, DR, LT, DV	Yes
	Lithospermum arvense	(L.) I. M. Johnst.	Field gromwell	Boraginaceae	AL, LT, DV	Yes
	Matricaria recutita	L.	German chamomile	Asteraceae	AL, LT, DV	
	Poa trivialis	L.	Rough bluegrass	Poaceae	AL, LT, DV	
	Stellaria media	(L.) Vill.	Common chickweed	Caryophyllaceae	AL, DR, LT, DV	Yes
	Thlaspi arvense	L.	Field penny-cress	Brassicaceae	AL, DR, LT, DV	Yes
	Tripleurospermum perforatum	(Mérat) Lainz	Scentless chamomile	Asteraceae	AL, LT, DV	
	Viola arvensis	Murray	Field pansy	Violaceae	AL, DR, LT, DV	Yes
Switzerland	*Valerianella locusta*	L.	Corn salad	Valerianaceae	AL, AR, CN, HP	
	Melilotus albus	(L.) Medik.	Honey clover	Fabaceae	AL, AR, CN, HP	
	Brassica napus	L.	Rapeseed	Brassicaceae	AL, AR, CN, HP	
	Agrostemma githago	L.	Common corncockle	Caryophyllaceae	AL, AR, CN, HP	
	Camelina sativa	L. Crantz	False flax	Brassicaceae	AL, AR, CN, HP	
Philippines	*Chloris barbata*	Steud.	Swollen finger grass	Poaceae	(PC)	(?)
	Cyperus iria	L.	Rice flat sedge	Cyperaceae	(PC)	(?)
	Digitaria ciliaris	(Retz.) Koel.	Crab grass	Poaceae	(PC)	(?)
	Echinochloa crus-galli	(L.) P. Beauv.	Barnyard grass	Poaceae	PC	(Yes)
	Echinochloa glabrescens	Munro ex Hook. f.	Barnyard grass	Poaceae	(PC)	(?)
	Eleusine indica	(L.) Gaertn.	Goose grass	Poaceae	(PC)	(?)
	Heliotropium indicum	L.	Indian heliotrope	Boraginaceae	(PC)	(?)
	Ischaemum rugosum	Salisb.	Wrinkled grass	Poaceae	(PC)	(?)
	Leptochloa chinesis	(L.) Nees	Chinese sprangletop	Poaceae	(PC)	(?)
	Ludwigia octovalvis	(Jacq.) Raven	Longfruited primrose-willow	Onagraceae	(PC)	(?)
	Paspalidium flavidum	(Retz.) A. Camus	Yellow watercrown grass	Poaceae	(PC)	(?)
	Sphenoclea zeylanica	Gaertn.	Gooseweed	Campanulaceae	(PC)	(?)

Gastropods: AL = Spanish slug (*Arion lusitanicus* Mabille; syn.: *Arion vulgaris* Moquin-Tandon), DR = Grey field slug (*Deroceras reticulatum* O.F. Müller), AR = Red slug (*Arion rufus* L.), CN = Grove snail (*Cepaea nemoralis* L.), HP = Roman snail (*Helix pomatia* L.), PC = Golden apple snail (*Pomacea canaliculata* Lamarck). Earthworms: LT = common earthworm (*Lumbricus terrestris* L.), DV = European nightcrawler (*Dendrobaena veneta* Rosa; syn.: *Eisenia hortensis* Michaelsen).

[1] Parentheses indicate that experiments are planned.

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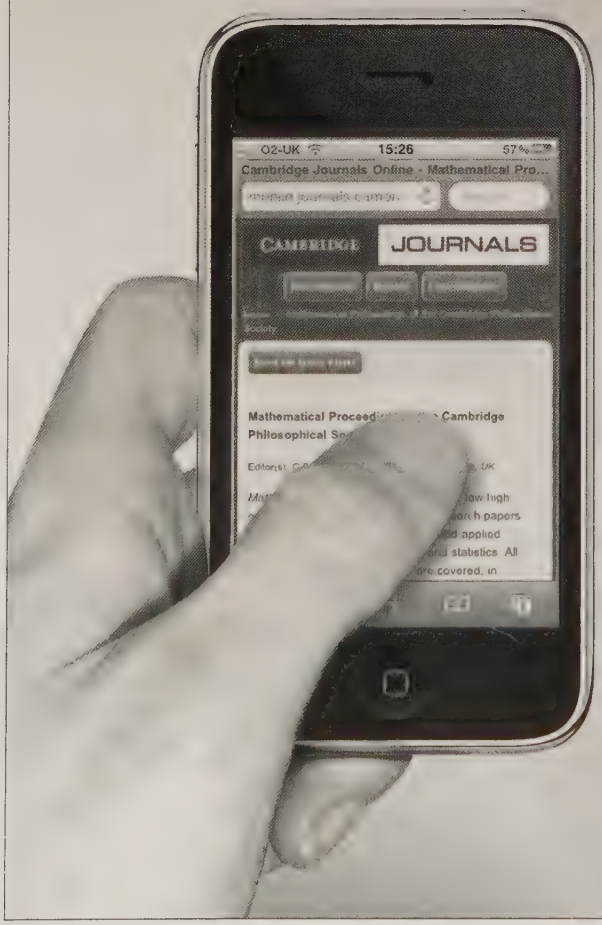

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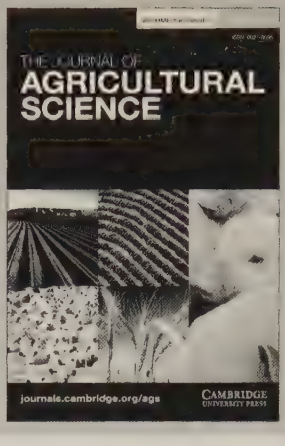

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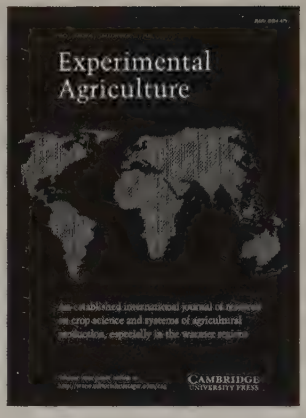

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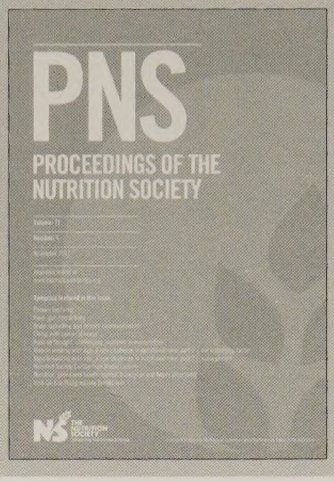

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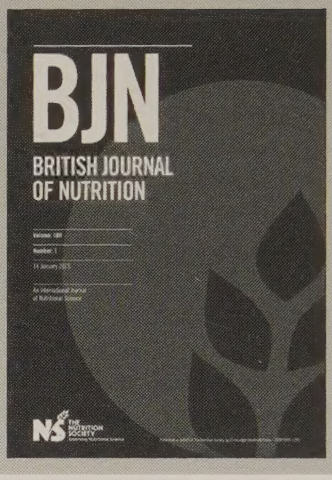

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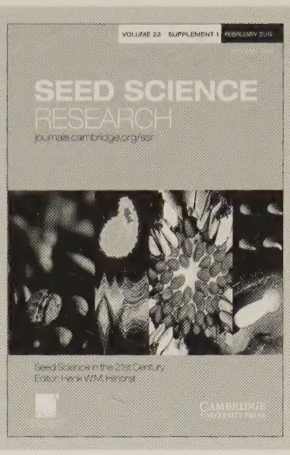

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Editorial
Rick Welsh 293

REVIEW ARTICLE

Organic agriculture in the United States: A 30-year retrospective
Garth Youngberg and Suzanne P. DeMuth 294

RESEARCH PAPERS

Comparing attitudes and characteristics of organic, former organic and conventional farmers: Evidence from Ireland
Doris Läpple 329

Evaluation of Ethiopian chickpea (*Cicer arietinum* L.) germplasm accessions for symbio-agronomic performance
Gemechu Keneni, Endashaw Bekele, Fassil Assefa, Muhammad Imtiaz, Tolessa Debele, Kifle Dagne and Emana Getu 338

Conservation agriculture systems for Malawian smallholder farmers: long-term effects on crop productivity, profitability and soil quality
Amos Robert Ngwira, Christian Thierfelder and Dayton M. Lambert 350

Esthetic and spiritual values motivating collective action for the conservation of cultural landscape—A case study of rice terraces in Japan
Pia R. Kieninger, Marianne Penker and Eiji Yamaji 364

FROM THE FIELD

Weeds and endangered herbs have unforeseen dispersal helpers in the agri-environment: gastropods and earthworms
Manfred Türke, Tamara Blattmann, Eva Knop, Anne Kindermann, Julia Prestele, Leonardo Marquez, Nico Eisenhauer and Christina Fischer 380

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